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FRYING PERFORMANCE OF CANOLA FATS AND OTHER COMMONLY USED FRYING FATS AND THEIR EFFECTS ON CHICKEN PATTIE QUALITY

BY

JEAN CHAW

(C)

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF
MASTERS OF SCIENCE

IN

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "Frying Performance of Canola Fats and Other Commonly Used Frying Fats and Their Effects on Chicken Pattie Quality"
submitted by Jean Chaw in partial fulfilment of the requirements for the degree of Master of Science in Foods

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Date: March 25, 1993

ABSTRACT

The effects of partially hydrogenated canola (PHC), hydrogenated canola (HC), partially hydrogenated soy (PHS), hydrogenated soy (HS) and tallow (T) frying fats on chicken pattie (CP) quality were determined. A trained QDA panel (n=9) evaluated 12 odor, flavor and texture attributes in CP. Instrumental/chemical methods were used to assess CP quality. Fat extracted from patties and performance of frying fat were assessed via chemical/instrumental methods.

Overall treatment means (OTM) of CP showed that HC, HS and T CP were similar and more chickeny in odor/flavor than PHC and PHS CP. The OTM showed that HC, HS and T patties were similar and more meaty in odor than PHC and PHS CP, but only more meaty in flavor than PHC CP. Patties fried in PHC and PHS had a more intense heated oil odor/flavor than HC, HS and T CP. Patties from all fats were low in rancid odor/flavor, but OTM for odor showed HS and T CP were similar and lower than other fats. Generally, sensory texture and juiciness data show few differences in CP attributable to frying fats. No differences due to fats were found for CP instrumental texture and juiciness data. Sensory CP aroma and flavor data correlated significantly ($p<0.001$) with UV absorbance ($E^{1\%}_{1cm}$) at 234 and 268 nm data for fats extracted from CP.

Data for used frying fats show that p-anisidine value and absorbance value ($E^{1\%}_{1cm}$) at 234 nm OTM for HS and HC were similar and lowest, followed by T, PHC and PHS which all

differed. Dielectric constant OTM for all frying fats were similar and low. Generally, all fats underwent minimal thermal degradation as measured by instrumental/chemical parameters indicating fats were of good quality after the 48 hr of heating. The GC analysis of heated fats showed pentane OTM for PHC was higher than PHS which also differed from T, HC and HS which were similar. The 2,4-decadienals OTM for PHS was higher than those of other fats which did not differ. The OTM for total volatiles in PHS was highest followed by PHC, and then T which was also higher than both HC and HS. Volatile constituents in heated fats showed highly significant relationships with CP sensory scores for chickeny, meaty and heated oil aromas/flavors.

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1. INTRODUCTION

The popularity of fried convenience foods has resulted in the use of significant quantities of frying fats in the food service industry (Orthoefer, 1987). Until 1986, animal-origin fats were the primary fats used by the food service industry for deep fat frying (Brooks, 1991). Recently, commercial frying operators have switched from the use of animal fats to partially hydrogenated vegetable oil based products (Brooks, 1991; Orthoefer, 1987). The change to use of vegetable fats for frying is due to health conscious consumers demanding more unsaturated fats and oils in product preparation (Brooks, 1991; Haumann, 1987). In addition, consumers want the nutritional benefits of fats to be available in fried foods without significant reductions in the sensory quality of convenience foods (Carr, 1991).

Desirable nutritional characteristics of canola oil combined with the acceptance by the United States Food and Drug Administration (FDA) have brought recognition of canola oil in the North American market (Orthoefer, 1987). Canola oil is the most important vegetable oil produced in Canada (USDA, 1990). Although canola oil is used extensively in Canada, information on its performance in frying is sparse (Orthoefer, 1987). Presently in the United States, soybean oil is the major oil used in cooking oils and shortenings (Warner et al., 1989). Like soybean oil, canola oil has been

used extensively to fry foods (Orthoefer, 1987). To date, there has been little published information describing the performance of canola frying fats in comparison with those commonly used (Stevenson et al., 1984b). If canola oil is to achieve its full potential in the North American market-place as a high quality frying fat, research comparing the frying performance and functional properties of canola and other commonly used frying fats is essential.

Thermal oxidation of linolenic acid, the most unstable fatty acid in canola and soybean oils, has been implicated as the cause of off-odors and flavors in heated fats (Prevot et al., 1990; Eskin et al., 1989; Miller and White, 1988a; Smouse, 1985; Vaisey-Genser and Ylimaki, 1985; Dobbs et al., 1978). Hydrogenation of vegetable oils, which lowers the level of linolenic and other unsaturated fatty acids, can be effective in producing a frying fat with increased thermal and oxidative stability, (Chu, 1991; Orthoefer, 1987; Snyder et al., 1986; Frankel et al., 1985). Stability and quality of vegetable frying fats are of great interest to oil processors and commercial frying operators for good frying fat performance at elevated temperatures (Chu, 1991). Partially and fully hydrogenated fats are marketed as heavy duty frying shortenings (Orthoefer, 1987; Snyder et al., 1986; Vaisey-Genser and Eskin, 1982). While much research has been focused on studying the thermal deterioration mechanisms and products

of unsaturated fats under laboratory conditions, relatively little information is available on the performance of hydrogenated vegetable fats in typical frying operations or under simulated frying conditions (Smith et al., 1986; Frankel et al., 1985). Therefore a comparison of the performance and quality of currently available partially hydrogenated and hydrogenated vegetable fats under simulated frying conditions is warranted.

The quality of fried convenience foods depends on the interaction of the frying fat and the food being fried (Blumenthal, 1991; Brooks, 1991). Breaded chicken products are commonly fried convenience foods (Hoogenkamp, 1988). Since the frying fat is absorbed by the food, the oxidative stability of the fat can affect the sensory quality of the fried food (Stevenson et al., 1984b). Data comparing the sensory quality attributes of convenience foods (french fries, chicken, fish) deep fried in canola fats and in other commonly used vegetable fats as well as tallow are limited. Thus research assessing the sensory quality of convenience foods fried in canola and soybean frying fats as well as tallow is pertinent.

This investigation was designed to study the effects of partially hydrogenated and hydrogenated canola fats and other commonly used (soybean and tallow) frying fats on the quality

attributes of fried chicken patties using sensory, instrumental and chemical methods. Since frying fats are absorbed by the food being fried (Blumenthal, 1991; Varela, 1988), the quality of fats extracted from fried chicken patties was determined via chemical methods. The frying performance of each fat was also assessed using chemical and instrumental methods.

2. LITERATURE REVIEW

Frying of Convenience Foods

Fried chicken parts, fingers, nuggets or patties are commonly fried convenience foods. Demand for chicken nuggets and related shapes has increased since their introduction in the early 1980's. These convenience chicken products are either whole chicken muscles or restructured meat that have a batter or breading and are deep fat fried (Hoogenkamp, 1988). The popularity of fried convenience products has resulted in the use of large quantities of frying fats and oils in institutions and food service outlets. Many of these food service outlets have menu items that evolve around deep fat fried convenience foods (Orthoefer, 1987; Lawson, 1985b).

Canola oil

The edible oil processed from the seeds of Brassica campestris and Brassica napus is known as "Canola oil". Canola oil is also used as the trade name for marketing this oil. Canola oil is the major vegetable oil produced in Canada (USDA, 1990). In 1990-1991, Canadian production of canola oil was 3,300,000 metric tonnes. In addition, 1990-1991 Canadian canola oil consumption increased by 14% to 360,000 metric tonnes from 309,000 metric tonnes in 1985/86 (Agriculture

Canada, 1991; USDA 1990).

Canola oil has a low (6%) saturated fatty acid content and relatively high levels of monounsaturated and polyunsaturated fatty acids (50-66% oleic (C18:1), 18-30% linoleic (C18:2), 6-14% linolenic (C18:3) acid) (Ackman, 1983; Vaisey-Genser and Eskin, 1982). Minimum requirements for canola oil include an erucic acid (C22:1) content of less than 5% of the component fatty acids (Carr, 1991; Daun, 1984; Vaisey-Genser and Eskin, 1982).

Desirable properties in fresh canola oil include light color, bland odor and flavor. The relatively high level of polyunsaturated fatty acids in canola oil, especially C18:3, may pose odor and flavor stability problems. Because it is highly unsaturated, heated canola oil, like soybean oil produces major aldehydes such as hexanal, 2-heptenal, 2-octenal and 2,4-decadienals (Wu and Chen, 1992) which are often characterized as "buttery", "grassy", "painty", "fishy" and "rancid", during various stages of thermal degradation (Prevot et al., 1990; Sinram and Hartman, 1989; Dobbs et al., 1978). Prevot et al. (1990) showed that low C18:3 (3.1%) canola oil was predominantly "fruity" and slightly "fishy" and had higher desirability scores overall than high C18:3 (7.3-11.3%) canola oil which was more "burnt", "rancid", "painty" and "fishy" even during the first of a total of eight frys. Researchers (Prevot et al., 1990; Eskin et al., 1989; Vaisey-Genser and Ylimaki, 1985; Dobbs et al., 1978) have related the

unpleasant heated odor and flavor of canola oil with C18:3 levels.

Canola oil may be partially hydrogenated or fully hydrogenated to provide desirable properties for deep frying. Commercial practice favors selective hydrogenation which is based on the degree of unsaturation of the fat and the tendency to add on hydrogen with a nickle catalyst; thus C18:3 with three double bonds tends to be hydrogenated first before C18:2 and C18:1, respectively (Vaisey-Genser and Eskin, 1982). As the double bonds of the fatty acids in the triglycerides become saturated during hydrogenation, the fatty acid composition is changed. This increase in saturation in hydrogenated fats results in a solid product with improved resistance to thermal degradation (Podmore, 1987; Mounts, 1985; Stevenson et al., 1984a; Patterson, 1983; Vaisey-Genser and Eskin, 1982; Landers and Rathman, 1980). Stevenson et al. (1984a) noted that hydrogenated (solid) fats with elevated melting points have been reported to have an oily mouthfeel.

Canola frying fats are designed for heavy duty frying in industry and institutions (Vaisey-Genser and Eskin, 1982). Table 1 gives the fatty acid content of typical canola frying fats. Dobbs et al. (1978) showed that hydrogenation of canola oil altered the fatty acid composition and improved the resistance of canola oil development of strong odors at high frying temperatures. Hydrogenated rapeseed (canola) oils

Table 1. Fatty acid content (%) of common frying fats[a].

Fatty acid composition (%)	PH[b] Canola	H[b] Canola	PH Soybean	H Soybean	Tallow
Myristic (C14:0)			0.1	0.1	2.8
Myristoleic (C14:1)					0.8
Pentadecanoic (C15:0)					0.5
Margaric (C15:1)					0.2
Palmitic (C16:0)	3.6	3.7	9.5	10.2	23.2
Palmitoleic (C16:1)	0.3	0.3	0.1	0.1	2.4
Heptadecanoic (C17:0)					1.7
Heptadecaenoic (C17:1)					0.9
Stearic (C18:0)	2.4	18.6	5.4	12.8	22.6
Oleic (C18:1)	75.8	71.1	56.3	73.8	39.9
Linoleic (C18:2)	10.5	2.4	25.3	1.4	1.9
Linolenic (C18:3)	2.7	0.4	1.5	0.1	0.6
Arachidic (C20:0)	0.6	0.9	0.3	0.4	0.2
Gadoleic (C20:1)	1.6	1.4	0.3	0.2	0.4
Behenic (C22:0)	0.3	0.4	0.3	0.4	0.1
Erucic (C22:1)	0.6	0.5			0.1
Lignoceric (C24:0)	0.2	0.2	0.1	0.1	
Nervonic (C24:1)	0.3	0.2			
Other	1.1		0.8	0.4	1.7

Source: POS Pilot Plant Corp. Saskatoon, Saskatchewan.

[a]Fats used in the present study.
[b]PH = Partially hydrogenated, H = Hydrogenated.

tended to have lower mean odor intensity (bland to strong) scores and lower thiobarbituric acid values (a measure of oxidative deterioration) than their unhydrogenated counterparts (Dobbs et al., 1978). Vaisey-Genser and Ylimaki (1985) noted the presence of unpleasant heated odors in oil with even trace amounts of C18:3. In addition, heated hydrogenated canola fats may have a "hydrogenated" odor and flavor which differ from a "heated oil" odor and flavor (Vaisey-Genser and Ylimaki, 1985). Thus sensory research to clarify and distinguish between "hydrogenated" and "heated oil" odors and flavors is warranted.

Soybean Oil

In 1990/1991, soybean oil was the main vegetable oil used in the United States (USDA, 1990), with production and consumption at 5.9 and 5.4 million metric tonnes, respectively. The fatty acid composition of soybean oil is similar to canola oil (Mounts, 1987). However, soybean oil has a lower C18:3 content (5.5-10%) and a higher C18:2 content (50-57%) than canola oil (Mounts, 1987).

During aging and heating, soybean oil frequently develops an undesirable odor and flavor, commonly referred to as flavor reversion (Smouse, 1985; 1979). In the initial stages of reversion, soybean oil has been described as "nutty" and "buttery"; reverted soybean oil is "beany", "grassy",

"rancid/painty" and "fishy" (Warner et al., 1989; Smouse, 1985; 1979; Warner and Frankel, 1985; Waltking and Goetz, 1983; Smouse and Chang, 1967).

Off-odors and flavors characteristic of flavor reversion can be produced when soybean oils are heated to frying temperatures (Miller and White, 1988a). Since C18:3 is the most unstable fatty acid in soybean oil, it is believed that the oxidation of C18:3 into its degradation products produces the off-odors and flavors (Smouse, 1985). Moreover, oxidation of C18:3 into its degradation products also catalyzes the oxidation of C18:2 which promotes further development of off odor/flavor in soybean oil. Thus off odor/flavor in soybean oil is not due to any one fatty acid but to a combination of compounds derived mainly from both C18:2 and C18:3 (Miller and White, 1988a; Smouse, 1985; 1979).

Researchers (Miller and White, 1988a; Mounts, 1979; Smouse, 1979; Evans et al., 1972) have found a relationship between high C18:3 content and the production of undesirable odors and flavors in heated soybean oil. However, Frankel et al. (1985) found no correlation between heated soybean oil C18:3 content and sensory flavor stability. Descrepancies noted in studies of heated soybean oil stability between sensory data and C18:3 levels may be attributed to poor sensory panel data or lack of guidelines as to describing off odor/flavor (Smouse, 1985). Further research on the flavor of heated soybean oil using reliable sensory methods is warranted.

Currently, soybean oils used for deep fat frying convenience foods are partially or fully hydrogenated. Table 1 shows the fatty acid composition of commonly used soybean frying fats. Partial hydrogenation of soybean oil improves both flavor and oxidative stability during deep fat frying compared to unhydrogenated soybean oil (Snyder et al., 1986; Frankel et al., 1985; Mounts, 1979; Cowan et al., 1971).

Handel and Guerrieri (1990) reported that polar compounds and acid values increased ($p<0.001$) at a greater rate in lightly hydrogenated soybean oil heated at 200°C for 24 hr, than in comparably heated highly hydrogenated soybean oil and tallow. The researchers (Handel and Guerrieri, 1990) concluded that frying fat stability as measured by acid value and percentage of polar compounds, roughly correlated with the degree of saturation of the oil. Therefore, highly hydrogenated soybean oil was more thermally stable at frying temperatures than lightly hydrogenated soybean oil.

In frying studies with bread cubes, Frankel et al. (1985) showed that unhydrogenated heated soybean oil gave the highest "fishy" response; however, highly hydrogenated heated soybean oil gave the highest "hydrogenated-paraffin" response. Earlier work by Yasuda et al. (1975) also documented a strong characteristic "hydrogenated" flavor in aged hydrogenated soybean oil. Frankel et al. (1985) noted that a characteristic "hydrogenated" flavor developed in highly hydrogenated soybean fat under their experimental frying

conditions. Thus they (Frankel et al. 1985) suggested that of unhydrogenated to fully hydrogenated oils, partially hydrogenated soybean oil was the most satisfactory for deep fat frying.

Tallow

The United States is the world's largest beef tallow producer, with production of tallow and greases reaching 6.7 million metric tonnes per year (USDA, 1990). Tallow accounted for 9.7% of the world's fats and oils production in 1990 (USDA, 1990). Tallow is used for deep fat frying. Since the consumption of deep fat fried convenience foods has increased, a market for tallow exists as an inexpensive alternative to vegetable oils.

Edible tallow is obtained mainly from beef cattle. Beef tallow is composed primarily of 52% saturated fat, 44% monounsaturated fat and 4% polyunsaturated fat (Vaisey-Genser and Eskin, 1982). However the fatty acid composition of tallow can vary with different processing conditions (Patterson, 1989). Table 1 shows the fatty acid composition of the tallow used in the present study.

Since tallow has a very low polyunsaturated fatty acid content, it is desirable in terms of oxidative stability. Less off-flavor compounds such as unsaturated aldehydes are present in heated tallow compared with vegetable oils such as

canola or soybean (Sinram and Hartman, 1989). The "waxy" mouthfeel noted in tallow fried food has been attributed to saturated fatty acids in tallow (Sinram and Hartman, 1989).

Tallow, unlike partially hydrogenated vegetable oils, exhibits a "conditioning" period during initial heating, where flavor volatiles develop gradually in intensity until they reach stable levels producing a full characteristic tallow flavor (Sinram and Hartman, 1989). This tallow flavor may be attributed to small amounts of amino acids, ammonia and proteins present in the fat reacting with aldehydes and ketones, degradation products of frying. Generally, the compounds formed give tallow fried french fries desirable meaty flavors (Sinram and Hartman, 1989). French fries cooked in tallow and tallow vegetable blends had the least off-flavor and scored equal to or better than french fries fried in partially hydrogenated soybean oil (Defouw et al., 1981). Defouw et al.(1981) concluded that tallow performed well physically as a typical commercial frying oil and that the resulting french fries were judged "favorable" by taste panelists. Using gas chromatography, Ha and Lindsay (1991) isolated volatile fatty acids present in tallow fried potatoes. The major fatty acids from the original beef tallow contributing to the meaty-tallow like flavors were butanoic, 2-methybutanoic, 3-methylbutanoic and heptanoic acids.

Due to recent increased nutritional awareness, consumers are demanding use of vegetable fats for deep fat frying.

Although vegetable oils are hydrogenated to simulate beef tallow, they may not be able to provide the characteristic beef-like flavor to fried foods. Sinram and Hartman (1989) and Haumann (1987) suggest that even though consumers may want to avoid the use of saturated fats, most are not ready or willing to give up flavor and convenience of their favorite foods. Thus comparative studies of the sensory quality of foods fried in beef tallow and vegetable fats are needed.

Kinetics of Fat Penetration

In deep fat frying, the food is completely immersed in oil or fat at a temperature above 160°C. The coating or batter present on most foods sets as the food is fried (Blumenthal, 1991; Guillaumin, 1988; Stevenson et al., 1984a). At about 100°C, the food surface becomes crisp as water is transformed into steam which produces a porous crust due to dehydration. After considerable water evaporation from the porous crust, fat replaces the cavities of the lost water. Oil absorption into the food during frying contributes to the fried odor, flavor and texture which in turn increase food palatability. With coated foods, fat penetration is peripheral and the inner part of the food is cooked by heat transfer (Guillaumin, 1988; Varela, 1988).

Blumenthal (1991; 1987) describes a surfactant theory of frying whereby decomposition products such as polymers and

dimers act as surfactants. A new oil has to be "broken-in"; initially there are few surfactants in the oil to cling onto the food against the gradient of escaping steam. Food fried for a constant time in new oil is lighter in color than food fried in degraded oil containing more surfactants. As the oil is used, surfactants increase and the contact time between the food and oil increases to an optimum giving fried foods a desirable color, flavor and texture. According to the surfactant theory, this contact time between oil and fried food is responsible for surface and interior differences of fried foods induced with aging oils (Blumenthal, 1991; 1987).

The Frying Process

During frying, fats are subjected to elevated temperatures in the presence of air and moisture. At high temperatures, fat oxidation, hydrolysis, thermal decomposition and polymerization are accelerated (Varela, 1988). These chemical reactions during frying change the functional, sensory and nutritional quality of a fat. Other factors which influence the fat decomposition rate include the type of food, whether the food has a coating or batter, the temperature of the fat, the frying vessel and the nature of the frying operation (Varela, 1988; Croon et al., 1986; Frankel et al., 1985; Stevenson et al., 1984a; Fritsch, 1981; Landers and Rathman, 1981; Chang et al., 1978).

Thermal Oxidation

Polyunsaturated fatty acids, particulary C18:1, C18:2 and C18:3 which are present in significant quantities in canola and soybean oils, are prone to thermal oxidation and are of concern in deep fat frying. Oxidation of these unsaturated fatty acids usually follows the route of a free radical chain mechanism (Smouse, 1985). At high temperatures, oxidation is accelerated and the rate of hydroperoxide formation is roughly proportional to the degree of unsaturation. Since C18:3 is more susceptible to oxidation than C18:2 and C18:1, a high C18:3 vegetable oil will oxidize at a faster rate (Frankel, 1985; Landers and Rathman, 1981). Oxidation can catalyze secondary oxidative or non-oxidative pathways (Gray, 1985). Decomposition products of oxidation are polar and non-polar compounds, hydrocarbons, aldehydes, ketones, alcohols and acids (Gutierrez Gonzalez-Quijano and Dobarganes, 1988).

Hydrolysis

During frying, fats can hydrolyze to form free fatty acids and mono- and diglycerides in the presence of water and high temperatures (White, 1991). Frying foods high in water content, such as meats and vegetables, at high temperatures can accelerate the rate of hydrolysis (Patterson, 1989; Gutierrez Gonzalez-Quijano and Dobarganes, 1988; Lawson,

1985a). Partial hydrolysis of frying fats will generate mono- and di-glycerides, free fatty acids and glycerol which may cause off-odor and flavor development (Patterson, 1989). Other factors which influence the rate of hydrolysis include quantity of food to be fried, crumbs or cracklings, and the rate of fat turnover (Lawson, 1985a; Fritsch, 1981).

Thermal Decomposition - Polymerization

Polymerization is related to thermal oxidation and hydrolysis. At high temperatures such as those used in deep fat frying, polymerization, especially of highly polyunsaturated fats occurs. During polymerization, free fatty acids from oxidation and hydrolysis, combine to form larger molecules such as dimers, cyclic monomers and polymers, by carbon-carbon linkages in the absence of oxygen (White, 1991). Polymerization rates can be affected by the time of heating, degree of unsaturation of the oil, frying fat quality, type of food and presence of oxygen. High temperature polymerization is characterized by "gum-like" deposits around the sides of the frying vessel and an increase in frying oil viscosity (Stevenson et al., 1984b). In very degraded oil, polymerization may cause foaming, oil darkening, increased viscosity as well as flavor and textural changes in the fried foods (Patterson, 1989; Gutierrez Gonzalez-Quijano and Dobarganes, 1988; Lawson, 1985a; Stevenson et al., 1984a).

Table 2 summarizes the principle pathways for the formation of frying fat decomposition products. These decomposition products can affect the flavor, color and texture of the fried food and the length of time the fat can be used for frying (Boskou, 1988).

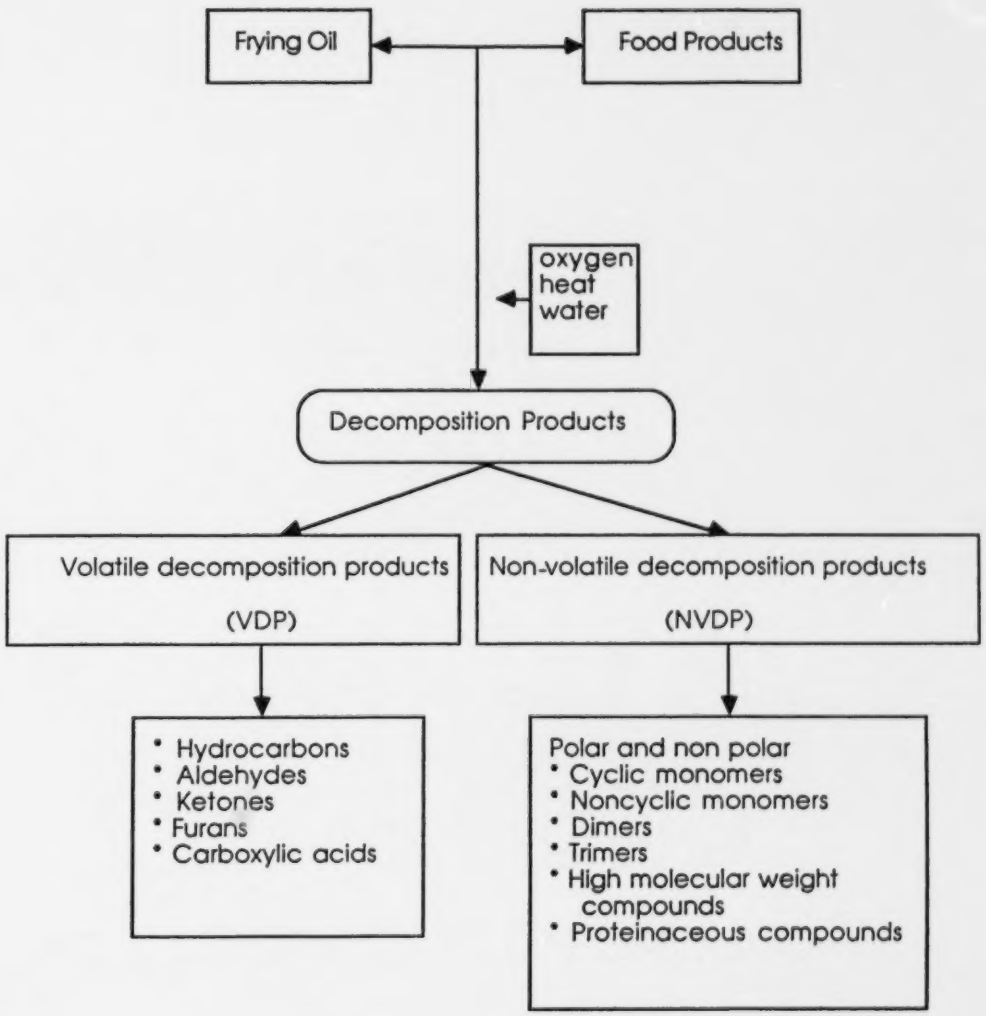
In general, decomposition products formed in frying oils (Figure 1) can be divided into two classes: volatile decomposition products (VDP) and non-volatile decompositon products (NVDP) (White, 1991; Stevenson et al., 1984a). Usually VDP are removed from the frying fat by steam generated during frying. Because they may be inhaled, VDP are of concern to frying operators. Some VDP may remain in the frying fat and be absorbed by the fried food. Since fried food flavor is partly derived from VDP, knowledge of their flavor composition may be important in producing fried foods of desirable flavor. Because of normal constraints in frying, VDP are not easily monitored; therefore more research has focused on NVDP (White, 1991; Stevenson et al., 1984a).

Since NVDP are in the frying oil, they are absorbed by the fried food and subsequently ingested when the food is consumed. Consumption of foods prepared from extremely degraded oil is self-limiting as excessive frying and formation of NVDP alters sensory acceptability of the oil and fried food (Clark and Serbia, 1991). Further fat degradation canbe accelerated upon NVDP accumulation. As fat degradation proceeds, NVDP increase in a somewhat linear progression

Table 2. Principle pathways for formation of frying fat decomposition products.

Type of pathway	Causative agent	Resulting compounds
Oxidation	Air	Oxidized monomers Oxidative dimers, polymers Non-polar dimers, polymers Volatile compounds (Hydrocarbons, aldehydes, ketones, alcohols, acids)
Hydrolysis	Moisture	Fatty acids Monoglycerides Diglycerides Glycerol
Thermal	Temperature	Cyclic monomers Dimers Polymers

(Adapted from Gutierrez Gonzalez-Quijano and Dobarganes, 1988)



(Adapted from Brooks, 1991; White, 1991)

Figure 1 . Formation of volatile decomposition products and non-volatile decomposition products in frying fats.

resulting in more reliable indicators of fat abuse. Most of the physical changes in heated frying fats include an increase in viscosity, color darkening, foaming and a decrease in smoke point. Chemical changes noted in heated fats are an increase in free fatty acids, carbonyl value, hydroxyl content, saponification value and a decrease in unsaturation, which result in the formation of high molecular weight products (White, 1991; Stevenson et al., 1984a; Paradis and Nawar, 1981).

Evaluation of Frying Fat Quality via Chemical/Instrumental Methods

A measure of the heat abuse taking place in a frying fat and an understanding of the products formed during deep fat frying are of great interest and importance to researchers, food service operators and the convenience food industry. Various objective criteria have been used to judge when a frying fat needs to be discarded; however, none of the methods has been completely satisfactory especially when different foods, fats and frying conditions are employed (Fritsch et al., 1979). Establishing when an oil is to be discarded also has significant economic advantages (Brooks, 1991; White, 1991; Asap and Augustin, 1986; Smouse, 1985; Fritsch, 1981; Paradis and Nawar, 1981).

Researchers (Hawrysh, 1992a; 1992b; Zhang and Addis,

1992; 1990; Chu, 1991; Hawrysh et al., 1991, Hawrysh et al., 1990a, Hawrysh et al., 1990b; Eskin et al., 1989; Augustin et al., 1987; Croon et al., 1986; Smith et al., 1986; Wu and Nawar, 1986; Vaisey-Genser and Ylimaki, 1985; Stevenson et al., 1984b; Paradis and Nawar, 1981; Fritsch et al., 1979; Billek et al., 1978) have used a variety of different methods to assess frying fat quality. Many of these chemical and physical methods of monitoring frying fat quality are based on measurements of the formation of VDP and NVDP. Procedures which have been widely used and have been adopted as standard tests for measuring frying fat quality are peroxide value, absorbance ($E^{1\%}_{1cm}$) at 234 and 268 nm, free fatty acids, iodine value, p-anisidine value, color, smoke point and viscosity. Recently, gas chromatographic methods and dielectric constant measurements using a Foodoil sensor have received much attention (White, 1991; Chu, 1991). The German Society of Fat Science proposed the determination of total polar components, gas liquid chromatography and free fatty acids as methods to complement sensory evaluation of frying fats (Croon et al., 1986). It is difficult to use one particular method as the ideal for quality control of frying fats (White, 1991; Stevenson et al., 1984a). The advantages and limitations of each test need to be addressed (Smouse, 1985; Fritsch, 1981).

The iodine value (IV) indicates the degree of unsaturation of an oil. The Wijs method (AOCS, 1979), used to

determine IV, is based on the uptake of iodine at the unsaturated double bonds of fatty acids and the subsequent titration of the excess by sodium thiosulfate. Thus the IV of a fat is the number of grams of halogen absorbed by 100 g of the fat expressed as the weight of iodine. During oxidation, IV is used to determine fat degradation due to the loss of polyunsaturated fatty acids (Morton and Chidley, 1988; Waltking et al., 1975). In assessing heated soybean oil, Chu (1991) found high correlations between IV and other methods of determining fat degradation such as dielectric constant. However, Stevenson et al.(1984b) did not find any significant changes in IV for unheated and heated (37.5 hr) canola and soybean fats.

The initial products of lipid oxidation are hydroperoxides which are generally referred to as peroxides. The AOCS official peroxide value (PV) iodometric method cd8-53 (1979) employs titration. The degree of oxidation is determined by the amount of iodine a fat liberates from potassium iodide expressed as milliequivalents of peroxide per 1000 g of fat. A fresh fat should have a PV of nil or less than 1.0 meq/kg (Stevenson et al., 1984a).

Although peroxides are unstable at very high frying temperatures, PV may be a good indicator of initial stages of oxidation (Gwo et al., 1985; Smouse, 1985). However, researchers (Zhang and Addis, 1992; 1990; Paradis and Nawar,

1981; Miller and White, 1988a; Gwo et al., 1985; Lawson, 1985a; Smouse, 1985; Stevenson et al., 1984a; Fritsch, 1981; Fritsch et al., 1979) have noted that PV is not always reliable because of limitations in determining titration end points (Gwo et al., 1985). Peroxide value may also be of limited use for oils with low levels of oxidation (Smouse, 1985). Furthermore, Zhang and Addis (1992) showed PV in heated oil increased to a maximum at 24 hr and then declined with further heating. They (Zhang and Addis, 1992) suggested that PV declined due to inherent thermal instability of the peroxyl bond. Paradis and Nawar (1981) found that PV could not correctly rank fats according to hours of frying. Zhang and Addis (1990) reported a low correlation coefficient between PV and total hours of heating. Stevenson et al. (1984b) noted that PV showed little change from the beginning to the end of the frying period.

Some researchers (Eskin et al., 1989; Evans et al., 1972) have reported good correlations between PV and sensory scores with heated fats. Others (Zhang and Addis, 1992; 1990; Stevenson et al., 1984b; Paradis and Nawar, 1981) have shown that PV are not fully capable of predicting flavor scores with heated fats. A PV of up to 10 meq/kg may be necessary before sensory odor and flavor differences can be detected (Patterson, 1989; Lawson, 1985a).

p-Anisidine values (AV) have been used to indicate secondary oxidation products, specifically saturated and unsaturated aldehydes (IUPAC, 1987; Smouse, 1985). In the presence of acetic acid, p-anisidine reacts with aldehydes to form a yellow compound which can be measured at 350 nm (IUPAC, 1987). In general, a fresh oil should have an AV between 1.0-10.0 (Smouse, 1985; Stevenson et al., 1984a). Since the aldehydes produced by oxidation are oil specific, data for AV should only be compared within oil type (Patterson, 1989). Chu (1991) showed a high correlation (0.816) between AV and dielectric constant values. List et al.(1974) reported significant correlations (0.68) between AV and flavor scores of soybean oil.

The free fatty acid (FFA) content of a heated fat is a measure of the extent to which hydrolysis has liberated fatty acids from their ester linkage with the parent glyceride molecule (Zhang and Addis, 1992; Rossell, 1986). The FFA method employs rapid colorimetric determinations. In the presence of cupric acetate, the FFA produced in fats form complexes of cupric soaps of saturated fatty acids which can be measured at 715 nm (Lowry and Tinsley, 1976). A common analytical specification for a fresh frying oil is a percent free fatty acid value of 0.05-0.08% (Stevenson et al., 1984a). German legislation suggests oil to be degraded if a FFA content of 1% is reached (Firestone et al., 1991; Stevenson et

al., 1984a). In a frying fat, FFA development is affected by the moisture content of the food and the frying temperature.

Analysis of the percentage of FFA has been suggested as the method of choice for determining frying fat deterioration (Stevenson et al., 1984a). Smith et al.(1986) and Stevenson et al.(1984b) have shown good correlations between FFA and heated frying fat deterioration and have suggested it to be a reliable method. The percentage of FFA is frequently determined in fast food establishments to monitor oil quality (Zhang and Addis, 1992). Others (Croon et al., 1986; Fritsch, 1981) have found FFA determinations to be an unreliable measure of frying fat deterioration.

Ultraviolet absorbance values ($E^{1\%}_{1cm}$ at 234 and 268 nm) measuring conjugated diene (CD) and triene (CT) hydroperoxides are quick ways of assessing oxidation of frying oils (Gray, 1985; St. Angelo et al., 1975). Oxidation of polyunsaturated oils is accompanied by conjugation of double bonds and therefore should lead to a progressive increase in light absorbance in the ultraviolet region. The IUPAC method 2.505 (IUPAC, 1987) measures this progressive increase in the light absorbance in the UV region on a fat sample dissolved in a suitable dilution (1%) of iso-octane. Ultraviolet absorbance at 234 nm and 268 nm can detect CD and CT hydroperoxides, respectively. This UV absorbance method is more useful for measuring oxidation in vegetable oils containing

polyunsaturated fatty acids such as C18:3 and C18:2 than in saturated fats (White, 1991; Gwo et al., 1985; Gray, 1985; St. Angelo et al., 1975). As UV absorbance values rely on the type and quantity of the polyunsaturated fatty acids present, absorbance values should be a relative measurement of oxidation within the same oil type (Lawson, 1985b).

Some researchers (Tsoukalas and Grosch, 1977; St. Angelo et al., 1975) have reported UV absorbance values ($E^{1\%}_{1cm}$) at 234 and 268 nm) to be reliable measures of the status of vegetable frying fats. Increased levels of CD and CT hydroperoxides in heated fats and oils have been reflected by increases in absorbance at 234 and 268 nm (Augustin and Berry, 1983; Gere, 1982). However, Gwo et al.(1985) found prolonged heating (100 hr) of animal-vegetable fats at high temperatures showed a decline in absorbance values ($E^{1\%}_{1cm}$ at 234 nm). They (Gwo et al., 1985) suggested that CD and CT may breakdown further into other degradation products which may not be detected at 234 or 268 nm, respectively. Gwo et al.(1985) also showed that UV absorbance values are not fully capable of predicting flavor scores of fried foods.

The color test is commonly used to measure the accumulation of NVDP in fats during frying (White, 1991; Stevenson et al., 1984a). Fat darkening is attributed to the presence of unsaturated carbonyl compounds or non-polar compounds from foodstuffs in the heated fat (Gutierrez

Gonzalez-Quijano and Dobarganes, 1988). Color development can be assessed by measuring oil absorbance at 363 nm (Gwo et al., 1985). High correlations between color darkening and heating time in frying fats have been reported (Stevenson et al., 1984b). However, evaluating soybean oil quality, Chu (1991) found color of fat could not be used as an adequate indicator of fat deterioration during frying.

The dielectric constant (DC), measured using a Foodoil sensor, is a quick method to estimate frying oil degradation (El-Shami et al., 1992; White, 1991; Fritsch, 1981; Fritsch et al., 1979). As the fat degrades, the number of polar materials present increase resulting in a corresponding increase in the DC (Wu and Nawar, 1986; Fritsch, 1981). For reliable Foodoil sensor results, Fritsch et al.(1979) suggested the following precautions: warming up the instrument to obtain stabilized readings and ensuring that the fresh oil used to standardize the instrument was not over heated. Since different frying fats generally have specific DC, the Foodoil sensor must be calibrated with the specific fresh oil used in the frying operation prior to use (White, 1991; Fritsch, 1981; Fritsch et al., 1979). During deep fat frying, factors such as water and fat from fried food may also influence Foodoil sensor readings (White, 1991). A DC of 4.0 is recommended as the cut off point for discarding a used fat (Chu, 1991; White, 1991; Paradis and Nawar, 1981; Fritsch et al., 1979).

Several researchers have compared Foodoil sensor readings to other methods of evaluating changes in frying fats. High correlations between DC and polar compounds (Chu, 1991, Croon et al., 1986; Smith et al., 1986; Wu and Nawar, 1986; Fritsch et al., 1979) have been reported. Croon et al. (1986) showed that Foodoil sensor measurements produced a high correlation (0.94) with the standard method for the determination of polar components. Paradis and Nawar (1981) found that a DC reading of 3.7 corresponded to 27% polar compounds, also a suggested indicator of poor quality oil. Fritsch et al.(1979) reported high correlations for DC with polar components (0.99) and FFA (0.56). Other researchers have correlated DC with PV (Zhang and Addis, 1990; Augustin et al., 1987; Paradis and Nawar, 1981; Fritsch et al., 1979), IV (Chu, 1991; Augustin et al., 1987; Fritsch et al., 1979), AV (Chu, 1991) and carbonyl values (Chu, 1991) and have found highly significant ($p<0.001$) relationships.

Although VDP form a small proportion of the total decomposition products in heated frying fats, they have a substantial detrimental impact due to the production of characteristic off-odors and flavors (Miller and White, 1988b; Warner and Frankel, 1985). Gas chromatographic (GC) methods ranging from direct injection to various purge-trap systems (Engeseth et al., 1992) have been used to determine volatile secondary oxidation products present in heated oils and their

contribution to sensory odor and flavor (Engeseth et al., 1992; Hawrysh, 1992a; 1992b; Wu and Chen, 1992; Hawrysh et al., 1991; Snyder et al., 1986; Gwo et al., 1985; Min and Kim, 1985; Waltking and Goetz, 1983; Min, 1981; Jackson and Giacherio, 1977; Blumenthal et al., 1976; Warner et al., 1974).

Snyder et al. (1986), reported the principle components in the gas chromatographic profiles of heated soybean oil to be pentane, hexanal, 2-heptenal and 2,4-decadienals derived from hydroperoxides of C18:2, and 2,3-hexanal and 2,4-heptadienals derived from hydroperoxides of C18:3. Wu and Chen (1992) reported similar volatile constituents in heated soybean oil after deep fat frying and subsequent storage. They (Wu and Chen, 1992) also noted that hexanal which has a fatty grassy odor can easily oxidize to hexanoic acid, which is responsible for the "rancid" characteristic in heated fats. Hexanoic acid has a heavy acrid, fatty rancid odor (Wu and Chen, 1992). Engeseth et al. (1992) noted that pentane, hexanal, 2-heptenal, 2,4-heptadienals and 2,4-decadienals (principle volatiles of hydroperoxide decomposition) influenced oil quality. Hawrysh et al. (1992b) assessed heated (24 hr) canola and soybean fats to determine the sensory quality of french fries and reported that the pentane, hexanal and 2,4-decadienals content of the used heated frying fats related well with french fry oil flavor intensity. Similary, Warner and Frankel (1985) and Warner et al.(1974)

suggested that flavor stability of heated soybean oil could be estimated reliably by total volatiles, pentane and 2,4-decadienals. Janney et al., (1974) identified 2,4-decadienals, octenal and hexanal as major volatile compounds that may be associated with fresh fried chicken flavor. Other researchers (Hawrysh et al., 1992b; Jacobson et al., 1989; Rho et al., 1986; Min, 1981; Jackson and Giacherio, 1977; Blumenthal et al., 1976; Warner et al., 1974) have correlated the production of volatiles in the heated fats with the sensory evaluation of the fried foods.

Hydrogenation of soybean oil improves oxidative stability during deep fat frying compared to unhydrogenated oil (Snyder et al., 1986; Frankel et al., 1985). Snyder et al. (1986) studied the effects of hydrogenation on volatile constituents in heated soybean oil and found a decrease in the total volatile formation with increasing hydrogenation. Research on gas chromatographic profiles of heated hydrogenated canola fats used for frying convenience foods is lacking.

Smoke point determinations give an index of frying fat deterioration. The smoke point of a fat is the temperature (°C) at which the fat produces a bluish grey steady stream of smoke (Stevenson et al., 1984a). Canadian Government specifications require that a good quality commercial frying fat has a smoke point of over 200°C (Stevenson et al., 1984a; Lawson, 1985a). Most European countries recommend that a fat

has a smoke point of not less than 170°C (Firestone et al., 1991). The German Society of Fat Research has recommended 170°C to be used in conjunction with a concentration of petroleum ether oxidized fatty acids of 0.7%, as a basis for discarding used frying fats (Firestone et al., 1991; Stevenson et al., 1984b; Bracco et al., 1981; Billek et al., 1978).

As FFA develop with frying, the smoke point of the fat is lowered (Lawson, 1985a). Stevenson et al. (1984b) reported that canola and soybean fats reached temperatures below 170°C with 37.5 hr of heating. Hawrysh (1992b) found smoke points of heated (180°C$\pm$5°C) canola and soybean fats to be below 170°C after 18 hr of frying french fries intermittently. Stevenson et al.(1984b) showed a negative correlation between smoke point and heating time; however, liquid canola and soybean fats exhibited higher correlations than solid canola and soybean fats.

Viscosity measurements, an index of flow properties in fats, have been used to determine deterioration in heated fats. During heating, cyclic and high molecular weight compounds formed due to polymerization accumulate and increase fat viscosity (Gutierrez Gonzalez-Quijano and Dobarganes, 1988; Stevenson et al., 1984a, 1984b; Bracco et al., 1981; Fritsch, 1981). Bracco et al.(1981) found that frying fat viscosity increased with heating time in an exponential-like curve. High correlations between viscosity and heating time

of 0.92 and 0.95 for liquid soybean and canola oil, respectively, have been reported (Stevenson et al., 1984b).

Evaluation of the Quality of Fried Convenience Foods via Chemical/Instrumental Methods

Since the frying fat is absorbed by the food, the tests used to measure degradation in heated fats have been applied to fat extracted from fried foods to evaluate food quality (Hawrysh, 1992a; 1992b; Hawrysh et al., 1991; Asap and Augustin, 1986; Stevenson et al., 1984b). Some researchers have determined thiobarbituric acid values, hydroperoxide value (Stevenson et al., 1984b), absorbance ($E^{1\%}_{1cm}$) at 234 and 268 nm, color (Hawrysh, 1992a; 1992b; Hawrysh et al., 1991), PV, IV, FFA, and GC profiles (Hawrysh, 1992a; 1992b; Hawrysh et al., 1991; Stevenson et al., 1984b) for frying fats extracted from french fries. Miller and White (1988a) used PV and absorbance ($E^{1\%}_{1cm}$) at 234 and 268 nm on used and extracted soybean oil from bread cubes to assess fried food quality.

Instrumental methods have been employed to assess fried food quality. The Warner-Bratzler (WB) shear is commonly used to determine tenderness of meat products (Beilken et al., 1991; Dawson et al., 1991; Lyon and Lyon, 1990; Papa and Lyon, 1989; Bernal et al., 1988; Smith et al., 1988; Pomeranz and Meloan, 1987; Poste et al., 1987; Lyon and Hamm, 1986; Moller,

1981; Yang and Chen, 1980; Stanley and Swatland, 1976; Uebersax et al., 1978). Usually, the maximum peak force required to shear through a meat sample of a fixed cross-sectional area at right angles to the sample has been determined (Smith et al., 1988; Moller, 1981). Workers (Moller, 1981; Szczesniak and Torgeson, 1965) have criticized the use of the WB shear because correlations between tenderness by shear force and sensory analysis are inconsistent. Since peak force values tend to relate to toughness of muscle bundles rather than to connective tissue, variability between samples for sensory testing and objective measurements is expected (Moller, 1981). Lyon (1987) noted that individual chicken muscle may differ in texture. Elimination of textural differences by choosing minced or restructured meat products for sensory evaluation, allows panelists to focus on sensory perceptions of mouth and nose (Lyon, 1987). As a result of his work (Lyon, 1987) on sensory testing of chicken pattie products, Lyon (1987) noted a potential for use of an Instron Universal Testing Machine with a Warner-Bratzler shear attachment to evaluate tenderness on minced or restructured meat products with increased reliability.

Objective methods for assessing meat juiciness are related to water holding capacity. Stanley and Swatland (1976) described a press technique using a Carver Laboratory

press. In their method (Stanley and Swatland, 1976), the free water in the meat samples is determined via pressing (1 min at 880.7 Kg/cm^2) and the pressed meat is weighed immediately to determine moisture loss. Free water can be calculated as weight of "free" water divided by total moisture in the sample. Young et al.(1987), using a method similar to that of Stanley and Swatland (1976), determined moisture retention in chicken breast meat patties. Others (Salmon et al., 1988; Poste et al., 1987) have used a Carver Laboratory press to determine water holding capacity on turkey breast muscle.

Fried chicken color can be described by characteristics such as lightness, hue and chroma (Pomeranz and Meloan, 1987). Lightness refers to the reflectance or absorbance of light, hue is the actual color and chroma refers to the saturation of the specific color (Pomeranz and Meloan, 1987). The Hunter Color Difference Meter is commonly used to determine food color instrumentally. The Hunter "L" value describes lightness-darkness, the "a" value denotes redness-greeness and the "b" value measures yellowness-blueness attributes (Pomeranz and Meloan, 1987). Various researchers have used the Hunter Color Difference Meter to measure color in battered fried chicken (Baker and Scottkline, 1988), poultry meat (Ahn and Maurier, 1990; McNeil et al., 1987) and turkey breast roll (Smith and Alvarez, 1988).

Sensory Evaluation

Sensory evaluation is extremely valuable in measuring food quality, since no instrument can percieve, analyze, intergrate and interpret a large number of sensations at the same time (Larmond, 1976b). Fried chicken pieces have been evaluated by sensory methods (Dawson et al., 1991; Baker et al., 1986; Porkony et al., 1982; Lane et al., 1980; Yang and Chen, 1980; Pereira et al., 1977; Baker et al., 1972; Funk et al., 1971; Berry and Cunningham, 1970; Hale, Jr. and Goodwin, 1968). While some researchers (Hawrysh, 1992a; 1992b; Zhang and Addis, 1992; 1990; Chu, 1991; Hawrysh et al., 1991, Hawrysh et al., 1990a, Hawrysh et al., 1990b; Eskin et al., 1989; Augustin et al., 1987; Croon et al., 1986; Smith et al., 1986; Wu and Nawar, 1986; Vaisey-Genser and Ylimaki, 1985; Stevenson et al., 1984b; Paradis and Nawar, 1981; Fritsch et al., 1979; Billek et al., 1978) have evaluated frying fat quality via chemical/instrumental methods, the sensory quality of the fried food is generally used as a guideline for discarding a used fat (Stevenson et al., 1984b; Jackson, 1981). Thus some workers have used trained panelists to assess the quality of fried products such as french fries (Hawrysh, 1992b; Stevenson et al., 1984b; DeFouw et al., 1981), battered fish (Flick Jr. et al., 1989) and bread cubes (Miller and White, 1988a; Frankel et al., 1985). However, sensory evaluations of fried chicken cooked in canola fats are

lacking.

Since panelists are used as measuring instruments, every effort must be made to control the effect of the environ ment on judgement (Warner, 1985; Larmond, 1977; 1973). Larmond (1973) outlined the importance of the physical requirements for sensory testing including an atmospherically controlled room and individual booths. Natural lighting is usually suitable for most samples. However, colored lights are sometimes used to mask color differences in samples. Color evaluations can also be performed using a MacBeth Skylight with a daylight setting (Larmond, 1977; 1973).

For sample preparation, every effort should be made to make the samples from different treatments uniform in all characteristics except the one being judged (Larmond, 1977). The Sensory Evaluation Committee of ASTM (1968) recommended that for discrimination tests, panelists should receive 28 g of a solid food sample and that the same amount of sample should be presented throughout testing (Larmond, 1977). Sample serving temperature should be that at which the food is normally eaten. Hot fried foods such as chicken patties should be served at 50°C$\pm$5°C (Lyon and Ang, 1990, Warner, 1985). Warner (1985) suggested the number of fried food samples presented to panelists in one session to be 2-4; however, up to 6 samples can be evaluated using the Quantitative Descriptive Analysis method (ASTM, 1981; Stone et al., 1974). Warm water (50°C$\pm$5°C)(Hawrysh et al., 1990a,

Hawrysh et al., 1990b; Stone and Hammond, 1983; Min, 1981; Larmond, 1977) and 1% lemon water (Hawrysh et al., 1990a, Hawrysh et al., 1990b; Funk et al., 1971) have been utilized for rinsing between samples of fatty foods. Distilled, room temperature water is also often given as the rinsing agent between samples (Larmond, 1977). Crackers, mild fruits and vegetables may be used to remove strong flavors (Larmond, 1977). By employing controls in sensory evaluation, many psychological errors that affect judgement can be avoided leading to results that are consistent and reliable (Larmond, 1973).

Cross et al.(1978) detailed training and testing of judges for sensory analysis of meat quality with a descriptive panel. The researchers (Cross et al., 1978) described four steps: (1) personal interview, (2) screening, (3) training and (4) performance evaluation. The importance of panel evaluation as an indicator of panel training was illustrated. Two panel evaluations should be performed, with the initial evaluation identifying specific problems during training and the second, after 2-3 weeks, assisting the panel leader to judge the results of training. The degree to which a person discriminates among samples in panel training and is consistent in replicate judgements is reflected in his F-ratios. Panelists with large F-ratios in a panel evaluation, indicate good discrimination and consistency; therefore, panelist ranking by F-ratios is a reliable screening method

during the training process (Cross et al., 1978).

Category scaling is frequently used to evaluate meat (Shand et al., 1985; IFT, 1981; Larmond, 1976a). Category scales consist of a series of word phrases structured in ascending or descending order of intensity for measuring certain attributes (IFT, 1981). Data from category scales can be used for correlations between chemical/instrumental measurements (IFT, 1981). For the evaluation of meat, most sensory researchers have adopted an eight point scale with attributes such as tenderness, juiciness and flavor (AMSA, 1978).

Quantitative Descriptive Analysis (QDA) is another popular sensory method (Sidel et al., 1981; Larmond, 1977; 1976b; Stone et al., 1974) that serves as an analytical tool to determine food quality. Stone et al. (1980) stated that QDA is a total system that includes sample selection, judge screening, language development, selection, training and performance of panelists, testing and data collection. A separate 15 cm line scale is used for each sensory property evaluated (Lyon and Ang, 1990; Lyon, 1988; 1987; Lyon et al., 1988; Stone et al., 1980; Larmond, 1976a) and each line scale, anchored at 1.0 cm from each end is labelled with a word or expression. Unstructured line scales with the verbal anchors at the ends only, as in QDA, have eliminated the problem of unequal intervals that is associated with structured scales (Larmond, 1976a). Therefore, unstructured QDA scales yield

greater product differences than category scales (Sidel et al., 1981; Larmond, 1977; 1976a, 1976b,; Stone et al., 1974).

The American Society for Testing and Materials (ASTM, 1981) has also outlined the selection, training, monitoring and performance of panelists for the QDA method. For QDA, twenty four to thirty six panelists should be screened for (1) taste acuity and reliability as demonstrated by the ability to duplicate a difference judgement; (2) the ability to deal analytically with a complex test situation; and (3) other pertinent factors such as health, interest, motivation and availability (ASTM, 1981). In QDA, screening is conducted by administering two sets of twelve triangle tests designed to expose judges to a broad range of discriminating tasks, such as those anticipated in the study. Ten to twelve individuals, minimum of six, from those who have correctly completed at least 66-75% of the screening test (ASTM, 1981) should be selected as panelists.

Because QDA is quantitative, it requires replicate responses from the individual panelists (Sidel et al., 1981). Replicate responses allow constant monitoring of panelist reliability and within sample variation. The QDA procedure also necessitates that each panelist evaluates products independent of other panelists after sessions of round table discussion. During discussions, panelists are encouraged to develop descriptors and samples are provided to illustrate the

different terms, so that the panel agrees on the meaning of each term.

A typical QDA training session involves as few as three and as many as five to six products (Stone et al., 1974). An advantage of using QDA is that it may utilize multiple samples to provide additional information and help characterize product similarities and differences (ASTM, 1981; Stone et al., 1974). Stone et al. (1974) outlined data collection and analysis of variance to measure individual and panel performance in QDA. Results of QDA are usually visually displayed in QDA diagrams which communicate the test results in a form that is readily understood with minimum discussion (Lyon and Ang, 1990; Lyon et al., 1988; Stone et al., 1980; Stone et al., 1974).

Several researchers (Ang and Lyon, 1990; Lyon and Ang, 1990; Lyon, 1988; 1987; Lyon et al., 1988) have used QDA in their poultry studies. In his study, (Lyon, 1987) seven to ten panelists used QDA to develop descriptors for cooked chicken pieces and patties. An initial 45-attribute list generated to describe flavor changes in cooked and reheated chicken pieces and patties was reduced to twelve terms (Table 3) using panel input and multivariate statistical techniques. Research using the QDA method to assess the quality of chicken patties fried in canola fats and other commonly used frying fats is lacking.

Because sensory response to a product is of concern to

Table 3. Twelve sensory descriptive attributes with definitions developed for evaluation of chicken flavor.

TERM	DEFINITION
Aromatic taste sensation	
Chickeny	Cooked white chicken muscle
Meaty	Cooked dark chicken muscle
Brothy	Chicken stock
Liver/Organy	Liver, serum or blood vessels
Browned	Roasted, grilled, broiled chicken
Burned	Excessive heating or browning
Cardboard/Musty	Cardboard, paper, mold, mildew
Warmed over	Reheated meat
Rancid/Painty	Oxidized fat
Primary tastes	
Sweet	Sucrose, sugar
Bitter	Quinine, caffeine
Feeling factors on tongue	
Metallic	Iron/copper ions

(Adapted from Lyon, 1987)

the developer, it is essential to also know how chemical andinstrumental methods compare with the human senses (IFT, 1981). Szczesniak (1987) identified why good correlations between sensory and chemical/instrumental data should be found: (1) the need for quality control, (2) the desire to predict consumer response, (3) the desire to understand sensory texture assessments and (4) the need to develop simple instrumental tests to duplicate sensory evaluation. Min and Kim (1985) state that an instrumental test should be inexpensive, sensitive and fully complement sensory evaluation. The QDA data from trained panelists have been correlated with chemical/instrumental tests for chicken products (Ang and Lyon, 1990; Lyon and Ang, 1990), french fries (Hawrysh, 1992b; Stevenson et al., 1984b) and heated canola oils (Eskin et al., 1989; Vaisey-Genser and Ylimaki, 1985). Studies assessing the relationships between data from highly trained panelists and instrumental/chemical tests for fried convenience foods such as chicken patties fried in canola fats are pertinent.

3. Methodology

An experiment was conducted to evaluate frying fat performance and quality of deep fried chicken patties cooked intermittently in each of five frying fat treatments. Chicken patties, fried in the fat treatments during each of the four 12 hr periods (12, 24, 36 and 48 hr of heating) were evaluated via sensory and chemical/instrumental measurements. Frying fat performance was assessed using chemical evaluation at 0, 12, 24, 36 and 48 hr and instrumental measurements at 12, 24, 36 and 48 hr of heating.

Materials Used for the Study

Commercial frying fats, each from a single processing batch, were obtained for the complete experiment. Partially hydrogenated (PH) canola fat was obtained from Canbra Foods, Lethbridge, Alberta and the remaining fats: hydrogenated (H) canola fat, partially hydrogenated (PH) soybean fat, hydrogenated (H) soybean fat and tallow were from Canada Packers, Edmonton, Alberta. All fats contained dimethylpolysiloxane (2 ppm) and monoglyceride citrate (50 ppm) as an antifoaming agent and antioxidant, respectively. The tallow also contained butylated hydroxyanisole (100 ppm)

Portioning and Frying of Fats

Portioning of fresh and used fats was standardized for determinations of frying fat quality. Partially hydrogenated canola and PH soy were portioned into bottles and vials; H canola, H soy and tallow were placed into double plastic bags. Appendix 2 shows the portioning of fats into bags, bottles or vials for chemical tests. All samples were flushed with nitrogen and stored at -30°C for later chemical analysis.

Cooking Procedure

Six home-style fryers (Seb Tefal^{R} Model 8215) equipped with new carbon filters and sponges (Tefal Accessory Pack no. 33305) were used for the study. The frying procedure was standardized during preliminary work. Fryers were sprayed with Pam^{R} non-stick cooking spray prior to use to facilitate later cleaning. Each fat was heated to 177$\pm$2°C for 3 hr prior to frying.

At each heating time, a total of 8 batches of chicken patties were fried in each fat treatment. Each batch of chicken patties (275 g) was placed in the frying basket of the deep fat fryer and lowered two thirds of the way into the hot frying fat. The fryer lid was closed and chicken patties were cooked (5 min 30 sec) to an internal temperature of 75$\pm$2°C, and drained (1 min). Each batch of patties was designated for

and butylated hydroxytoluene (100 ppm). All frying fats were stored at -30°C until required. Prior to each replication, one pail (case) of each fat was thawed (4°C, 48 hr) and a 2 kg portion was randomly assigned to fryers (Appendix 1).

Chicken patties (7.5 cm diam x 1.5 cm high), required for the study and for sensory panel training were made in one production run by the Alberta Agriculture Food Processing Development Center, Leduc, Alberta. The chicken pattie formulation consisted of 88.7% chicken breasts, 10.6% water and 0.64% salt by total weight. Chicken breasts were flaked and formed using a "240" head attachment in a Comitrol (Urschel Labs 3600 with feed screw). The flaked chicken, salt and water were mixed for 6 min. Formed patties were coated with a commercial batter and crumb (Griffith BA4700 batter:water, 1:1.8 : UFL Medium Deluxe Crumb) mix, delivered to the Department of Foods and Nutrition, University of Alberta and frozen (-30°C). A total of 8 batches, consisting of 4 patties per treatment, were portioned into plastic bags, labelled by batch order, heating time and replication and stored at -30°C. Prior to each heating (frying) time, one set of the 8 batches of chicken patties (the 32 patties required for frying during the 12 hr heating period) was stored at -18°C for 15 hr.

specific tests (Table 4).

After each 12 hr heating period, the used fat was filtered using the Tefal Filters and sampled for chemical and instrumental tests as described earlier. Each fryer was carefully cleaned, dried and sprayed with Pam^{R} cooking spray. The filtered fat was returned to the appropriate fryer and topped with fresh fat for the next heating period. After the completion of each replication, all fryers were washed thoroughly, fitted with new carbon filters and sponges, and the fats were randomly assigned to the fryers for the next replication.

Table 4. Batch allocation of chicken patties for tests in one frying period.

Time	Batch
6 am	0 = turn on fryers
8 am	1 = Extra batch
9 am	2 = Hunter color test
9.45 am	3 = Sensory A + Carver press[a]
10.45 am	4 = Sensory B + Instron[b]
2 pm	5 = Fat and moisture 1[c]
2.20 pm	6 = Fat and moisture 2
2.40 pm	7 = Fat and moisture 3
3 pm	8 = Extra batch
6 pm	0 = Turn off fryers

[a] Batch 3 chicken pattie samples were split into sensory panel 1 and instrumental test.
[b] Batch 4 chicken pattie samples were split into sensory panel 2 and instrumental test.
[c] Fat and moisture 1, 2, 3 chicken pattie samples were composited for fat extraction.

Objective Measurements

Instrumental Tests For Chicken Patties

Instrumental analyses on chicken patties included measurements of color, tenderness and juiciness.

Color

The external color of chicken patties was measured using a Hunter color difference meter (Hunter Associates Lab Inc, Model D25-2). For each replicate, the meter was calibrated with a set of standard color tiles. Before each heating period, the meter was standardized against the "L, a and b" values of the black (L=+0.0, a=+0.0, b=+0.0) and white (L=+92.7, a=-1.0, b=+0.3) color tiles. For testing, two fried chicken patties (22°C) were wrapped with Resinite^{R} food wrap and the top side of each pattie was placed directly over the large port in the inverted meter position. A black cover was placed on top of the pattie to block out external light. For each pattie, three sets of "L, a and b" values were recorded by rotating the pattie 90° twice, thus a total of 6 sets of "L, a and b" readings per treatment were obtained.

Tenderness

For each fat treatment, shear determinations were made on six chicken pattie cores (1.2 cm wide by 1.2 cm high) with and without coating. An Instron Universal Testing System (Model 4201) equipped with a Warner-Bratzler blade attachment and a

50 kg load cell was used. The down speed of the crosshead was set at 150 mm/min. Each core (22°C) was sheared twice. The peak force and peak force per gram required to shear through the sample were recorded. An average of 6 shear values per fat treatment was determined and values were reported as total force and force per gram.

Press Fluid

The percentage of press fluid in chicken patties from each fat treatment was determined using an adaptation of the method of Stanley and Swatland (1976). Three chicken cores were cut from one chicken pattie (22°C) per fat treatment. A sample (0.5-0.6 g) was cut from the center of the three cores for triplicate measurements. Tweezers and scalpels were used to minimize handling of the samples. Each weighed sample was pressed at a pressure of 880.7 Kg/cm^2 for 60 sec, using a Carver Laboratory Press (Fred S. Carver Inc. Model C12, Menomonee Falls, Wis.). The pressed sample was weighed again and the percentage press fluid was determined as the weight of the expressed fluid over the original weight of the unpressed sample.

Chemical Tests

The treatment frying fats and fats extracted from the chicken patties were analyzed by various chemical tests. The initial chemical properties of the fresh frying fats were defined via IV, PV and fatty acid composition. Fats extracted from chicken patties were assessed for IV, PV and absorbance ($E^{1\%}_{1cm}$) at 234 and 268 nm. Fats subjected to frying were analyzed for IV, PV, FFA, AV, absorbance ($E^{1\%}_{1cm}$) at 234 and 268 nm, color, DC and GC. Samples representing each frying fat treatment from each replication were analyzed in duplicate.

Fat and Moisture Content of Chicken Patties

Fat and moisture content of the chicken patties were determined using an adaptation of the method of Stevenson et al. (1984b). Fried chicken patties (725 g) from each treatment were thawed, cut into small pieces and placed in labelled beakers covered loosely with foil for freeze drying. Cut chicken samples were freeze dried in a Labconco. freeze drier (Model freeze dry12) for 72 hr. Percent moisture was determined by the difference in the wet and dry weight of the samples.

The fat content of freeze dried chicken patties was determined via a modification of the method of Miller and

White (1988a). Freeze dried chicken (125-150 g) was crushed in a blender (Waring Model 33bl73) on low (10 sec), stirred and then blended (high, 10 sec). The blended chicken was mixed with hexane (175 mL), stirred intermittently for 10 min and poured into a fritted disc filter attached to a water aspirator. The chicken hexane mixture was filtered into a 500 mL filtering flask. The filtered chicken was mixed with additional hexane (175 mL) and the mixing and filtering procedure was repeated. The filtered hexane containing extracted fat was poured into a round bottom flask of known weight and attached to a roto-evaporator (Buchi-Rotavapor-R) to evaporate the solvent at 55-60°C (rotospeed of 1). The amount of extracted fat was calculated as a percentage based on the weight of the chicken patties before freeze drying.

Iodine Value

Iodine values were determined by the Wijs method, AOCS Official Method Cd 1-25 (AOCS, 1979). The amount of sample used was fat specific. Partially hydrogenated canola and PH soy, 0.32-0.35 g, H canola and H soy, 0.4-0.45 g, and tallow, 0.6-0.65 g of fat, respectively. The fat sample was weighed into an Erlenmeyer flask to which 20 mL of carbon tetrachloride and 25 mL of Wijs solution were added. The flask was stored in a dark place for 30 min. The excess halogen was determined by the addition of potassium iodide solution (20 mL), followed by titration of the liberated

iodine with a standardized sodium thiosulphate solution (0.1N) and starch indicator solution (1 mL, 1%). The IV, which is the number of grams of halogen absorbed by 100 g of the oil, was expressed as the weight of the iodine.

Peroxide Value

Peroxide values were determined using AOCS Official Method Cd 8-53 (AOCS, 1979). A fat sample (5 g) was weighed into an Erlenmeyer flask containing 30 mL of glacial acetic acid:chloroform mixture (3:2 v/v). Saturated potassium iodide (0.5 mL) was added to the flask and the solution was shaken intermittently for 60 sec, then distilled water (30 mL) and starch indicator solution (0.5 mL, 1%) were added and the solution was titrated with sodium thiosulfate solution (0.01N). Peroxide values were expressed as milliequivalents of peroxide per 1000 g of sample.

p-Anisidine Value

p-Anisidine values (AV) were determined using the IUPAC Method 2.504 (IUPAC, 1987). A fat sample (0.5 g) was weighed into a 25 mL volumetric flask and diluted to the mark with iso-octane. The absorbance (350 nm) of this solution was measured with a spectrophotometer (Perkin-Elmer Lambda3B UV/VIS) with iso-octane (99%) as a blank, and the iso-octane was used as the blank for the calculation of the AV. Samples of the fat solution (5 mL) and iso-octane were then pipetted

into separate test tubes, p-anisidine reagent (1 mL) was added to each test tube and the tubes were mixed using a vortex (3 sec). Exactly 10 min later, the absorbance of the oil/p-anisidine solution was measured at 350 nm with the iso-octane/p-anisidine solution as a blank in the reference cell.

Free Fatty Acids

Free fatty acids in heated fat treatments were determined using methods adapted from Lowry and Tinsley (1976) and Stevenson et al.(1984b). A fat sample (0.1-0.2 g) was weighed into a screw cap test tube to which toluene (5 mL) and 5% cupric acetate solution (1 mL) were added and the test tube capped. A test tube shaker (Janke and Kunkel, typ vx2) set at 1400 was used to shake the biphasic system in the test tube for 2 min, and then the test tube was centrifuged (Sorvall RC2-B) for 5 min at 4000 rpm. Absorbance of the upper layer of the biphasic system was read against a toluene blank at 715 nm using a spectrophotometer (Perkin-Elmer Lambda 3B UV/VIS). For each sample run, the spectrophotometer was standardized (4 mL toluene, 1 mL 0.55 mg oleic acid in toluene). The %FFA were expressed as equivalents of oleic acid.

Ultraviolet Absorbance ($E^{1\%}_{1cm}$) at 234 and 268 nm

Ultraviolet absorbance ($E^{1\%}_{1cm}$) at 234 and 268 nm, measuring the production of conjugated diene and conjugated triene hydroperoxides in the samples according to IUPAC Method 2.505

(IUPAC, 1987). A fat sample (0.1 g) was weighed into a 10 mL volumetric flask and diluted with iso-octane. A sample (1 mL) of this fat solution was pipetted into another 10 mL volumetric flask and diluted with iso-octane. The absorbance of the solution with iso-octane as the blank was measured, using a Unicam SP1800 Ultraviolet spectrophotometer set at 234 nm and 268 nm, to represent conjugated diene and conjugated triene contents, respectively.

Color Determination

Color was determined by using a modification of the method of Gwo et al. (1985). A fat sample (1 g) was weighed into a 10 mL volumetric flask and diluted to the mark with hexane. The flask was shaken vigorously to ensure that all the fat was dissolved. Absorbance (363 nm) of the solution was measured against a hexane blank using a Unicam SP1800 UV spectrophotometer.

Dielectric Constant

Dielectric constants of the fats were measured with a Foodoil sensor oil quality analyzer (Model n1-21A, Northern Instruments Corp.). Readings reflect the change in fat polarity (dielectric constant) due to the presence of polar compounds in used fat compared to fresh fat with a zero dielectric constant (t=0). Fat samples (0.2 g) were removed from the fryers at 11, 23, 35 and 47 hr of frying. After a

one hr warm-up period, the Foodoil sensor was calibrated. Fresh fat (0.2 g, t=0) was used to standardize readings for each fat treatment. Readings for fresh fat were adjusted to zero and then the used oil (0.2 g) was measured.

Instrumental tests of Fresh and Used Fats

Instrumental analyses of fresh and used fats, performed in triplicate, included determinations of smoke point and viscosity. Hydrogenated canola, H soy and tallow samples were held in a water bath (60°C, 1 hr) to facilitate smoke point and viscosity determinations.

Smoke point

Smoke points were determined according to the standard method (Official method Cd 9a-48) of the AOCS (AOCS, 1979). A brass Cleveland open flash cup, ASTM designation D92-33, was filled with fat (65 g) to the filling line. The brass cup with fat sample was then placed in the Fisher/Tag Cleveland flash point open tester (set at 8). The flash point open tester was enclosed in a black box with one side open and a daylight bulb (100W) was mounted to shine light horizontally across the center of the brass cup. Bright lighting was required to facilitate detection of the smoke point. The fat sample was heated rapidly to within 30-40°C of the expected smoke point and then the sample was heated at a rate of 5-6°C

per min (tester setting 5). The smoke point was the temperature (°C), at which the fat sample gave off a thin steady stream of bluish smoke.

Viscosity

Viscosity was measured using a Brookfield Viscometer (Model RVTD) with a UL adapter at 60°C. A fat sample (14.5 g) was placed inside the UL adapter, which was then attached to the viscometer. The UL adapter and fat were allowed to equilibrate at 60°C for 1 min before the viscometer was turned on. A speed of 50 rpm corresponding to a factor of 1.28 was used to measure the viscosity. Readings were taken after 3 min 30 sec to allow the viscosity to stabilize.

Gas Chromatography

Off-flavor volatiles in the fat samples were analyzed using a Varian Model 3400 gas chromatograph (GC)(Walnut Creek, California) interfaced with a Tekmar Headspace Concentrator (Model LSC 2000, Cincinati, Ohio). The analytical method used was adapted from Snyder et al. (1985) and Selke and Frankel (1987). A fat sample (0.1 g) was weighed into a glass tube, heated and purged with helium in the Tekmar Concentrator at 160°C for 15 min. Volatiles from the fat sample were collected on a Tenax trap, then thermally desorbed at 180°C and cryogenically refocused for injection onto a Durabond-5-fused silica capillary column (30m x 0.32 mm ID, 1 micron film

thickness) (J & W Scientific, Rancho Cordova, California). The GC oven temperature was held at 40°C for 10 min and then programmed to 200°C at 5°C per min. Individual volatile compounds were identified by comparing retention times of the GC peaks with those of known standards and n-decane (25.8 ppm, 100 mg) was used as an external standard for quantitative evaluation of the GC data.

Sensory Methodology

For each replication, nine trained panelists evaluated aroma, flavor and textural characteristics of fried chicken patties. Chicken pattie samples from each treatment were evaluated on consecutive days during each frying period at 4, 16, 28 and 40 hr of heating.

Panel Selection and Training

Panelists were selected by the process described by Cross et al. (1978). Students and staff (n=25) in the Department of Foods and Nutrition, University of Alberta, participated in the screening process, which consisted of a series of 16 triangle tests. The chicken tested was a commercial chicken finger product. The samples evaluated were cooked by different methods for varying times, and fried in used and flavored (mild fishy to strong fishy) fats. Twenty one panelists were selected for training on the basis of their

ability to correctly identify the odd sample greater than 60% of the time, their interest and availability for the duration of the study.

Training sessions were held 3 to 4 times per week for 13 weeks. Each session was approximately one half hour in duration and employed QDA (Stone and Sidel, 1985; Stone et al., 1974) and Spectrum™ methods (Meilgaard et al., 1987) for sensory evaluation. Quantitative descriptive analysis round table, conference style discussions with a panel leader were employed during the early training sessions. The first session introduced panelists to sensory evaluation and aquainted them with evaluation procedures. Panelists evaluated commercial fried chicken finger samples for aroma and flavor. In the second and third sessions, judges used the QDA method with a 15 cm unstructured line scale anchored with 0=none and 15=extreme. When scoring the chicken sample, each panelist was instructed to place a vertical line across the horizontal line which best described his impression of the intensity of the aroma and flavor. At each round table session, panelists were presented with reference (good quality) chicken fingers fried in fresh tallow. Panelists were encouraged to generate descriptors for specific aroma and flavor notes.

Samples presented during subsequent training sessions were designed to acquaint panelists to odor and flavor

characteristics anticipated in the fried chicken during the study. Thus chicken samples were fried in different fats and/or in fats heated for varying times to represent fresh and used fat. Panelists were asked to score the reference sample first and then subsequent samples in relation to the reference. To assist panelists in describing and detecting different aroma and flavor notes, a range of other samples was prepared. These included: vials of cod liver oil, butter, used (rancid) fat, fresh heated fat, white chicken meat and roast beef as samples to represent "fishy", "buttery", "rancid", "heated oil", "chickeny" and "meaty", respectively. A list of aroma and flavor descriptive terms (Lyon, 1987) was also provided (Appendix 3) to aid panelists in their evaluations.

After the 6th training session, a preliminary scorecard with the four most common and appropriate descriptors was provided to panelists for subsequent training sessions. Descriptors for chicken pattie aroma and flavor included "chickeny", "meaty", "heated oil" and "rancid". Tenderness was also introduced with a 15 cm line scale. Panelists were acquainted with the procedure for evaluating tenderness. They were asked to count the number of chews to completely masticate a sample as an indication of tenderness.

Throughout these training sessions, it was difficult to obtain uniform chicken finger samples. Thus to provide a consistent chicken product, a breaded, flaked and formed

chicken pattie was introduced to panelists in the 12th training session. Round table discussion ensured that panelists used the same descriptors for specific aroma and flavor notes in the patties.

During the next 9 training sessions, conducted in the sensory evaluation room, panelists were given a revised scorecard with a total of 13 aroma and 13 flavor attributes. Panelists were asked to identify these attributes in the samples and to score the intensity of each attribute on unstructured line scales. Panelists were also introduced to the Computerized Sensory Analysis program (CSA, 1990). After each session, the panel leader discussed specific strengths and weaknesses with each panelist. During this time, 7 of the 21 panelists resigned due to lack of availability and personal reasons.

The training sessions also used the Spectrum™ method (Meilgaard et al., 1987) which emphasizes the "custom design" approach to panel training and questionnaire development. The Spectrum™ method uses reference points and reference samples derived from data collected over several replications. During the 14th to 16th sessions, panelists used the 15 cm line scales to rate reference chicken samples for specific aroma and flavor attributes. For each attribute on each line scale, reference points, based on mean scores for reference chicken samples, were established (Appendix 4).

During the 17th to 20th sessions, a panel evaluation

(Cross et al., 1978) was conducted. The evaluation consisted of 4 replications of 5 treatments representative of those anticipated in the study and a reference. Aroma and flavor intensity data were analyzed by a one-way analysis of variance using SAS statisical software (SAS, 1985). Panelist F-values for each characteristic combined with standard errors were used to assess panelists' performance. Panelists with high F-values indicated good discrimination and consistency. On the basis of F-values, 5 panelists were dropped from the panel. Another panelist dropped out due to personal reasons. Individual F-values and panelist means obtained from the panel evaluation were also examined and feedback based on the results was provided to each panelist to refine the scoring.

On the 21st session, panelists were introduced to the technique for evaluating juiciness. Juiciness of chicken patties was evaluated using a raisin (Woodwards seedless raisins) as a temporary reference until the chicken reference sample was anchored. In this session, each panelist was also given an individual chew range card developed in relation to the reference chicken pattie for scoring tenderness.

A second panel evaluation was conducted as descibed earlier. The evaluation consisted of four replications and data collected were analyzed by a one way analysis of variance. No panelists were dropped. Based on the second panel evaluation results, evaluation of the low intensity

aroma and flavor characteristics (means less than 10%) was discontinued. To accomodate a shorter questionnaire, space was provided and panelists were encouraged to write additional comments, where appropriate.

Color evaluation was introduced during the 24th training session. A USDA color standards chart for frozen french fries (Munsell Color, Baltimore, Maryland), with an intensity scale was used. The anchor points, intensity of 1 (light brown) and intensity of 4 (dark golden brown) were positioned on the 15 cm line scale at 5 cm and 10 cm, respectively. Outside edges of the chicken pattie crusts were removed to eliminate color unevenness and patties were presented randomly on white coded plates. Panelists scored the color of chicken patties in the Macbeth Skylight (Northern Daylight, 7500 °K).

In the last week of training, the final scorecard was produced along with refined procedures for evaluating each attribute (Appendices 4 and 5). Final performance feedback was given by the panel leader to each panelist.

Sample Presentation and Data Handling

For each of the 3 replications, panel sessions were held daily (between 10 and 11 am) for four days per week in an atmospherically controlled sensory panel room equipped with individual booths, each with a computer station and red lights. At each session, each panelist received a total of 7 samples to evaluate 5 treatments, a hidden reference, and one

reference sample. The order of sample presentation was randomized for each panelist. Each panelist evaluated chicken samples from each fat treatment x heating time once per replication for a total of three replications. For presentation to panelists, fried patties were cooled (1 min), cut into 12 wedges and pooled to give a composite sample per treatment. A wedge shape was selected to provide the maximum amount of crust for aroma and flavor evaluation. The samples, three chicken pattie wedges per treatment or reference, were placed randomly on heated white plates, divided into 7 sections. Prior to tasting, the samples were warmed to 55°C ± 5°C covered with individual aluminum foil caps and held at this temperature on Salton™ hotrays. Room temperature lemon water (1%) was provided to panelists to cleanse the mouth before tasting and for rinsing between samples.

Panelists evaluated the samples using the CSA computerized sensory analysis program, version 4.1 (CSA, 1990). Sensory data were statistically analyzed with SAS (SAS, 1985).

Experimental Design and Statistical Analysis

A strip-plot experimental design (Milliken and Johnson, 1984) involving fat treatments and heating time was used. The design for one replicate is shown in Figure 2. All data were subjected to the analysis of variance. Sources of variation

Frying Fat Treatments[1]					
Hours of heating[a]	PH[b] Canola	H[b] Canola	PH Soy	H Soy	Tallow
12 hr					
24 hr					
36 hr					
48 hr					

[a] For chemical tests, a fresh fat sample with 0 hr of heating was evaluated.
[b] PH = Partially hydrogenated; H = Hydrogenated.

[1] 1 replication.

Figure 2. Experimental design used for the study.

consisted of fat treatments (t=5), heating times (h=4 for sensory and instrumental tests; h=5 for chemical tests), replications (n=3) and for sensory panel data, panelists (p=9). Student-Newman Keul's Multiple Range test (Steel and Torrie, 1980) was used to identify significant differences among treatment means. Overall correlation analyses were performed to assess relationships between appropriate sensory and chemical/instrumental data.

4. Results and Discussion

Sensory Analysis of Fried Chicken Patties

Daily throughout sensory analysis, panelists evaluated chicken pattie samples fried in treatment fats as well as samples fried in fresh tallow and presented as a known reference (REF) and a hidden reference (HREF). The HREF was used solely for the purpose of monitoring panelists' ability to detect a fresh chicken pattie sample.

Means and standard errors for sensory aroma data for chicken patties fried in the different fat treatments for up to 48 hr are presented in Table 5. At 12 hr, no significant differences in chickeny aroma were found among patties fried in the treatment fats. After 24 hr of frying, H canola, H soy and tallow patties were similar and significantly ($p<0.001$) higher in chickeny aroma than PH canola and PH soy patties. At 36 hr of frying, except for PH canola patties which were significantly ($p<0.001$) lower in chickeny aroma than tallow samples, patties fried in all the fat treatments were similar. As frying progressed to 48 hr, the chicken patties from PH canola, H canola and PH soy did not differ but were less chickeny in aroma than H soy and tallow patties which were similar. Treatment means for patties fried in each of the fats over 48 hr indicate that the H fats and tallow patties

Table 5. Means and standard errors for aroma intensity values[1] for fried chicken patties.

Aroma[2] note	Hr of heating	Frying Fat Treatment					SEM[4]
		PH[3]Canola	H[3]Canola	PH Soy	H Soy	Tallow	
Chickeny	12	5.10	6.76	5.05	7.10	6.16	0.44[ns5]
	24	5.02[b]	6.20[a]	5.07[b]	6.47[a]	5.94[a]	0.16***
	36	4.77[b]	5.36[ab]	5.20[ab]	5.64[ab]	6.18[a]	0.23*
	48	4.71[b]	5.02[b]	5.06[b]	5.97[a]	6.08[a]	0.18***
	$\bar{X}$[6]	4.90[b]	5.83[a]	5.10[b]	6.29[a]	6.09[a]	0.14***
Meaty	12	4.89	5.55	5.01	5.73	5.40	0.27[ns]
	24	4.72	5.47	4.96	5.42	5.39	0.17[ns]
	36	4.43	5.20	4.74	5.45	5.42	0.26[ns]
	48	4.35[d]	5.03[bc]	4.70[cd]	5.36[ab]	5.67[a]	0.15***
	$\bar{X}$	4.60[b]	5.32[a]	4.85[b]	5.49[a]	5.47[a]	0.11***
Heated oil	12	5.93[a]	4.43[b]	6.00[a]	4.05[b]	4.70[ab]	0.33**
	24	6.06	5.00	6.72	4.95	5.22	0.42[ns]
	36	6.40[ab]	5.76[ab]	7.13[a]	5.75[ab]	4.95[b]	0.40*
	48	6.75[ab]	6.23[bc]	7.06[a]	5.61[c]	4.67[d]	0.20***
	$\bar{X}$	6.29[a]	5.35[b]	6.73[a]	5.09[b]	4.88[b]	0.17***
Rancid	12	3.40	2.25	3.45	1.03	1.96	0.51[ns]
	24	3.79	2.99	3.50	2.50	2.63	0.28[ns]
	36	3.83[a]	3.96[a]	3.85[a]	3.08[ab]	2.60[b]	0.24*
	48	3.84	4.30	3.23	2.54	3.00	0.48[ns]
	$\bar{X}$	3.72[a]	3.38[a]	3.51[a]	2.29[b]	2.55[b]	0.21***

[1]Values are means of 27 scores (9 panelists and 3 replications).
[2]15 cm linescale, 0 = none 15 = extreme.
[3]PH = Partially hydrogenated, H = Hydrogenated.
[4]Standard error of the mean.
[5]Not significant.
[6]Treatment mean computed across 12-48 hr of heating.
[abcd]Means within the same row sharing a common letter are not significantly different at $p<0.05$.
*, **, *** Significant at $p<0.05$, $p<0.01$ and $p<0.001$, respectively.

were similar and significantly ($p<0.001$) higher in chickeny aroma than patties fried in the PH fats.

Data for meaty aroma of patties fried in the treatment fats did not show significant differences up to 36 hr of frying. After 48 hr, H soy and tallow patties were the same and higher ($p<0.001$) in meaty aroma than those from other fat treatments, however H soy and H canola patties did not differ; H canola patties were also similar in meaty aroma to PH soy samples which in turn were not significantly different from those fried in PH canola with the lowest ($p<0.001$) meaty aroma. Overall treatment means for 48 hr of frying show that H fat and tallow samples were similar and scored higher ($p<0.001$) in meaty aroma than patties fried in both PH fats. During frying, a characteristic meaty aroma and flavor can develop with heated tallow (Sinram and Hartman, 1989) which may explain the higher meaty aroma scores noted by panelists for patties fried in tallow rather than the PH vegetable fats after 48 hr.

At 12 hr of heating, patties cooked in both PH canola and PH soy had significantly ($p<0.001$) higher heated oil scores than those from the H fats. Tallow samples were similar to patties from the PH and H fat treatments. At 24 hr, no differences in heated oil aroma were found among patties fried in the fat treatments. As frying progressed (36 hr), all

treatment patties were similar in heated oil aroma except that PH soy patties had a significantly ($p<0.05$) higher heated oil aroma than tallow patties. After 48 hr, heated oil aroma in patties fried in PH soy was higher ($p<0.001$) than in the H fat patties, but PH canola and H canola patties had similar heated oil aroma. Tallow patties had the lowest heated oil scores. Examination of overall treatment means showed similar and higher ($p<0.001$) heated oil scores for patties fried in PH canola and PH soy than those of the H fats and tallow, which did not differ.

At each frying time, patties from all treatments had generally low rancid aroma scores and, except after 36 hr of heating, no differences in rancid aroma were found among patties fried in the fat treatments. At 36 hr, tallow patties exhibited the lowest ($p<0.05$) rancid aroma but they did not differ from those fried in H soy, which also were similar to patties from the other treatment fats. Throughout the 48 hr of frying rancid aroma in PH fat samples tended to be relatively constant; however, rancidity in patties from H fats and tallow tended to increase with fat use. Averages over the 48 hr, show that patties fried in H soy and tallow were similar and significantly ($p<0.001$) lower in rancid aroma than those from PH canola, H canola and PH soy.

Sensory aroma data for chicken patties indicate that the

H fats resulted in samples with higher chickeny and meaty but lower heated oil aromas than patties from the PH fats. Compared to unhydrogenated vegetable fats, hydrogenation of vegetable fats may enhance frying fat stability (Snyder et al., 1986; Dobbs et al., 1978) thus producing less off odors (Dobbs et al., 1978). In their sensory tests, Dobbs et al. (1978) noted that compared to unhydrogenated oils, hydrogenated heated canola fats had decreased odor intensity and lower thiobarbituric acid values, indicating less oxidative breakdown. Findings of the present study showed when heated oil and rancid aroma scores were high in the PH fat treatment patties, panelists' ability to detect chickeny and meaty aromas tended to decrease.

Chickeny, meaty and heated oil aromas in patties fried in the H vegetable fats and tallow were similar. Therefore these findings suggest that H canola and H soy may be as acceptable to the traditionally used animal fat for deep fat frying foods such as chicken. The slightly better performance of H soy over H canola in terms of rancid aroma may be attributed to the extent of hydrogenation between the fats. The H canola fat contained slightly more C18:3 than H soy (Table 1 page 8). The noticeable heated oil and rancid aroma scores detected in patties fried in PH canola and PH soy (high C18:3 treatment fats) are possibly a consequence of the thermal oxidation of C18:3 (Prevot et al., 1990; Sinram and Hartman, 1989; Miller and White, 1988a; Smouse, 1985; 1979; Dobbs et al., 1978).

Sensory flavor data (Table 6) for chicken patties fried in the treatment fats resembled those for aroma (Table 5). After the initial 12 hr frying period, no significant differences in chickeny flavor were found among patties from the treatment fats. After 24 hr, patties from the H fats and tallow were similar and more ($p<0.01$) chickeny in flavor than those fried in the PH fats which were the same. At 36 hr, both H soy and tallow patties were significantly ($p<0.05$) higher in chickeny flavor than those from PH canola; however PH canola samples did not differ from H canola and PH soy patties which in turn were similar to H soy and tallow samples. After 48 hr, H soy and tallow patties were similar and significantly ($p<0.01$) higher in chickeny flavor than PH canola and H canola samples; however, PH soy and H soy patties did not differ. Throughout the 48 hr period, treatment means for H soy and tallow patties tended to have similar and significantly ($p<0.001$) higher chickeny flavor than other treatment patties, and H canola samples did not differ from those of tallow. Patties fried in the PH fats were lower ($p<0.001$) in chickeny flavor than patties from other fat treatments.

At 12, 24 and 36 hr of frying, data for meaty flavor of patties showed no significant differences due to fat treatments. Except for tallow patties which were significantly ($p<0.05$) higher in meaty flavor than those from

Table 6. Means and standard errors for flavor intensity values[1] for fried chicken patties.

Flavor[2] note	Hr of heating	Frying Fat Treatment					SEM[4]
		PH[3]Canola	H[3]Canola	PH Soy	H Soy	Tallow	
Chickeny	12	5.05	6.56	5.06	7.03	6.17	0.42[ns5]
	24	4.71[b]	6.05[a]	4.86[b]	6.41[a]	5.88[a]	0.20**
	36	4.80[b]	5.40[ab]	5.30[ab]	5.90[a]	6.10[a]	0.23*
	48	4.86[c]	5.03[c]	5.28[bc]	5.97[ab]	6.29[a]	0.22**
	$\bar{X}$[6]	4.86[c]	5.76[b]	5.13[c]	6.33[a]	6.11[ab]	0.14***
Meaty	12	4.01	4.53	4.32	4.34	4.24	0.20[ns]
	24	3.76	4.37	3.87	4.20	4.36	0.21[ns]
	36	3.84	4.35	3.97	4.51	4.27	0.20[ns]
	48	3.58[b]	4.21[ab]	4.01[ab]	4.21[ab]	4.73[a]	0.17*
	$\bar{X}$	3.80[b]	4.36[a]	4.04[ab]	4.31[a]	4.40[a]	0.10***
Heated oil	12	5.26[a]	3.12[b]	5.36[a]	2.87[b]	3.61[b]	0.39**
	24	5.10	4.06	5.94	4.14	4.51	0.46[ns]
	36	5.66[ab]	5.19[ab]	6.12[a]	4.77[ab]	4.17[b]	0.36*
	48	5.95[a]	5.61[a]	5.93[a]	4.70[a]	3.65[b]	0.28***
	$\bar{X}$	5.49[a]	4.50[b]	5.84[a]	4.12[b]	3.99[b]	0.18***
Rancid	12	2.86[a]	1.33[b]	2.69[a]	0.78[b]	1.52[b]	0.28**
	24	2.90	3.09	2.17	2.15	2.58	0.44[ns]
	36	2.07[b]	3.29[a]	2.73[ab]	2.53[ab]	2.47[ab]	0.19*
	48	2.42	3.45	1.76	2.45	2.98	0.61[ns]
	$\bar{X}$	2.57	2.79	2.34	1.98	2.39	0.20[ns]

[1]Values are means of 27 scores (9 panelists and 3 replications).
[2]15 cm linescale, 0 = none 15 = extreme.
[3]PH = Partially hydrogenated, H = Hydrogenated.
[4]Standard error of the mean.
[5]Not significant.
[6]Treatment mean computed across 12-48 hr of heating.
[abc]Means within the same row sharing a common letter are not significantly different at $p<0.05$.
*, **, *** Significant at $p<0.05$, $p<0.01$ and $p<0.001$, respectively.

PH canola, all treatment patties were similar at 48 hr. Meaty flavor scores for all treatment patties tended to remain consistent throughout the 48 hr. Averages over the 48 hr of frying indicate that patties from the H fats and tallow were similar and had higher ($p<0.001$) meaty flavor than PH canola samples. However PH soy patties did not differ from those of PH canola and the other treatment patties in meaty flavor.

At 12 hr of frying, patties fried in PH fats were similar and significantly ($p<0.01$) higher in heated oil flavor than patties cooked in the H fats and tallow which were the same. After 24 hr, panelists detected no significant differences in heated oil flavor among patties due to fat treatment. After 36 hr, PH soy patties had higher ($p<0.05$) heated oil flavor than tallow patties. Patties from the other fat treatments were similar. After 48 hr, except for tallow patties which had the lowest ($p<0.001$) heated oil flavor, all other treatment patties did not differ. Throughout the frying period, data for heated oil flavor of patties from PH fats and tallow tended to remain stable; however, patties cooked in the H vegetable fats tended to increase in heated oil flavor as frying progressed. Average means over 48 hr show patties fried in the H fats and tallow had lower ($p<0.001$) heated oil flavor than those fried in the PH fats.

At 12 hr, patties cooked in the PH fats were

significantly ($p<0.001$) higher in rancid flavor than those from H fats and tallow which were similar. After 24 and 48 hr, panelists detected no significant differences in rancid flavor among patties due to fat treatment. Except for H canola patties which were higher ($p<0.05$) in rancid flavor than those from PH canola, all patties were similar after 36 hr. Over the entire frying period, all chicken patties generally exhibited very low levels of rancidity. Rancidity scores in PH fat patties tended to remain stable over the 48 hr frying period; however, rancid flavor in H fat and tallow patties increased slightly with fat use.

Generally, the data suggest that chicken patties from H fats and tallow tended to have more chickeny flavor than those from PH fats. Fried foods such as french fries cooked in tallow may exhibit desirable meaty flavors (Sinram and Hartman, 1989). However in the current study, patties fried in the PH and H vegetable fats generally did not differ in meaty flavor from tallow cooked patties. Heated oil and rancid scores of chicken patties also did not show large differences due to fat treatment. However, compared to those from the H fat and tallow treatments, patties fried in PH fats tended to have a more noticeable heated oil flavor.

In the present study, PH canola and PH soy contained higher amounts of C18:3 than the H fats (Table 1 page 8). Higher C18:3 levels may account for the significant

differences in sensory characteristics found in the fried chicken patties. Chicken patties fried in PH fats tended to have higher heated oil aroma and flavor than those fried in the H fats and tallow. Generally, H fat patties did not differ in aroma and flavor from tallow fried patties. Use of H canola and H soy which were similar in C18:3 content and lower in C18:3 than PH fats improved fried chicken pattie quality by reducing some of the undesirable heated oil and rancid aroma and flavor notes. Increased flavor stability in patties fried in heated H fats may be attributed to a decrease in the amount of C18:3 content compared to C18:3 contents of unhydrogenated or partially hydrogenated fats (Eskin et al., 1989; Miller and White, 1988a). Research on fried chicken pattie sensory quality is lacking, however, Miller and White (1988a) evaluated the flavor of breadcubes fried in soybean oils of different fatty acid composition heated for 40 hr and found that breadcubes fried in low C18:3 content soybean oil were ($p<0.05$) "superior" to those fried in oils with higher C18:3 content. In contrast, Frankel et al. (1985) noted that hydrogenation of soybean oil to lower C18:3 content improved oil stability based on chemical analysis, yet did not improve the flavor of fried breadcubes.

Findings similar to those of the current study were reported by Hawrysh (1992b) and Hawrysh et al. (1991). Hawrysh et al. (1991) investigated the frying performance of canola fats heated for up to 24 hr and the sensory quality of

french fries. They found significant differences in oil flavor intensity among fries cooked in PH canola and H canola and those cooked in PH soy and H soy. For oil flavor intensity, the overall means of H canola fries were lowest, followed by those cooked in PH canola, H soy and tallow which were similar and PH soy french fries were most intense in oil flavor (Hawrysh et al., 1991).

Means and standard errors for the sensory texture and color of chicken patties are shown in Table 7. Generally scores for oily mouthcoating for patties from all fat treatments did not vary during the entire frying period. At 12 hr, both PH canola and PH soy patties were significantly ($p<0.01$) higher in oily mouthcoating than those from H canola and H soy which were the same. Tallow patties did not differ in oily mouthcoating from other patties. As frying progressed at 24, 36 and 48 hr, panelists' detected no significant differences in oily mouthcoating among patties due to fat treatments. Highly saturated fats, such as H canola, H soy and tallow when used for deep fat frying may contribute to a "waxy" oily mouthfeel in fried foods (Sinram and Hartman, 1989). In the present study, no differences in oily mouthcoating of patties attributable to fat use were found. However, in their french fry study, Stevenson et al. (1984b) reported that as heating time increased panelists noted sensory differences in oily mouthcoating in french fries

Table 7. Means and Standard errors for sensory texture and color scores[1] for fried chicken patties.

Sensory[2] note	Hr of heating	Frying Fat Treatments					
		PH[3]Canola	H[3]Canola	PH Soy	H Soy	Tallow	SEM[5]
Oily mouthcoating	12	3.16[a]	2.06[b]	3.06[a]	2.15[b]	2.65[ab]	0.19**
	24	3.08	2.88	3.05	2.80	3.11	0.36[ns6]
	36	2.49	3.02	3.29	3.02	2.65	0.33[ns]
	48	2.53	3.42	2.77	3.09	2.66	0.31[ns]
	$\bar{X}$[4]	2.81	2.84	3.04	2.77	2.77	0.14[ns]
Tenderness[7]	12	5.71[a]	6.09[a]	4.81[b]	6.01[a]	5.66[a]	0.18**
	24	6.00	6.07	5.63	5.78	6.17	0.43[ns]
	36	5.27	6.58	5.37	6.32	5.77	0.28[ns]
	48	5.57	5.94	5.11	6.29	6.02	0.34[ns]
	$\bar{X}$	5.64[ab]	6.17[a]	5.23[b]	6.10[a]	5.91[a]	0.17**
Juiciness[8]	12	6.87[b]	6.55[b]	7.79[a]	6.40[b]	6.77[b]	0.18**
	24	6.71	6.11	7.08	6.70	6.37	0.43[ns]
	36	7.60[a]	6.42[b]	7.33[ab]	6.46[b]	6.65[ab]	0.24*
	48	7.39	6.80	7.65	6.18	6.46	0.32[ns]
	$\bar{X}$	7.14[a]	6.47[b]	7.46[a]	6.44[b]	6.56[b]	0.17***
Color[9]	12	6.80	5.19	6.98	6.36	6.39	1.10[ns]
	24	7.35	5.12	7.03	6.65	7.35	0.94[ns]
	36	7.96	5.51	8.42	6.24	5.21	0.80[ns]
	48	8.82	5.90	7.15	7.68	6.29	0.98[ns]
	$\bar{X}$	7.73[a]	5.43[b]	7.40[a]	6.73[ab]	6.31[ab]	0.45**

[1]Values are means of 27 scores (9 panelists and 3 replications).
[2]15 cm linescale, 0 = none 15 = extreme.
[3]PH = Partially hydrogenated, H = Hydrogenated.
[4]Treatment mean computed across 12-48 hr of heating.
[5]Standard error of the mean.
[6]Not significant.
[7]0 = extremely tender, 15 = extremely tough.
[8]0 = extremely dry, 15 = extremely juicy.
[9]0 = extremely light, 15 = extremely dark.
[a,b]Means within the same row sharing a common letter are not significantly different at $p<0.05$.
, * Significant at $p<0.01$ and $p<0.001$, respectively.

cooked in PH canola. Panelists judged french fries cooked on day 1 to have significantly ($p<0.05$) less oily mouthcoat than french fries cooked on any of the other 10 frying days (Stevenson et al., 1984b).

At 12 hr, tenderness scores for chicken patties showed significant ($p<0.01$) differences due to fat treatment. Except for PH soy patties which were more tender, all other treatment patties were similar in tenderness. As frying progressed (24-48 hr), no differences in tenderness were found among patties fried in the fats. Means over 48 hr, showed that PH soy patties were more ($p<0.01$) tender than H canola, H soy and tallow patties; however PH soy patties did not differ in tenderness from the PH canola patties.

Except for 24 hr and 48 hr of frying, significant differences in juiciness of chicken patties fried in the treatment fats were found. At 12 hr, PH soy patties were more ($p<0.01$) juicy than patties from other fats. After 36 hr of frying, PH canola patties were significantly ($p<0.05$) more juicy than those cooked in both H canola and H soy. However, PH canola patties did not differ from PH soy and tallow patties which were the same and did not differ from those cooked in the H fats. Treatment means over 48 hr show that PH canola and PH soy patties were more ($p<0.001$) juicy than patties from the H fats and tallow.

After each of the frying periods, no differences in color among patties from the fat treatments were found. Treatment means over 48 hr show that H canola patties had a lighter ($p<0.01$) color than both of the PH fat patties; however, H canola patties did not differ from H soy and tallow patties, which in turn were similar to those cooked in the PH fats.

Generally, except for a few differences in tenderness, juiciness and color, patties from all fat treatments were similar. Overall color evaluation (12-48 hr), showed that PH fat patties were darker in color than those cooked in H fat and tallow. The small but significant differences found in the overall color of fried chicken patties may be explained by Blumenthal's (1991; 1987) surfactant theory of frying, where decomposition products (acting as surfactants) of fat degradation can influence the contact time between the frying fat and the fried food. Since hydrogenation may increase fat stability (Snyder et al., 1986; Dobbs et al., 1978) fewer surfactants may be formed in H fats and tallow during heating. The presence of fewer surfactants in H fats may reduce the food/fat contact time and result in patties with a lighter color compared to those from PH fats. Hawrysh et al. (1991) found no significant differences in crust crispness, oily mouthcoating, interior texture and color of french fries due to frying fats. Research on sensory texture and color of chicken products fried in currently used frying fats is

lacking.

Quantitative descriptive analysis diagrams are usually presented to visually display sensory data in a form that is readily understood (Stone et al., 1980). Figure 3 presents QDA diagrams depicting the sensory attribute profiles of chicken patties from the fat treatments evaluated in the present study. The diagrams also show sensory chicken pattie data (a) for the first heating period (at 12 hr) and (b) for the overall treatment means ($\bar{X}$) computed across 12-48 hr. The differences in the chicken patties due to fat treatments described earlier are readily apparent.

Instrumental Measurements of Chicken Patties

At each frying time, no significant differences in instrumental measurements of chicken patties attributable to the fat treatments were determined. Thus means and standard errors for instrumental tests on patties computed across 12-48 hr of heating are presented in Table 8. However, trained panelists detected significant differences in the tenderness and juiciness of the fried chicken patties due to frying fat (Table 7). Thus in the current study, panelists were more able to detect small differences in sensory texture and juiciness among the chicken patties from the frying fats than the instrumental tests. Published information regarding the effects of frying fats on the tenderness and juiciness of

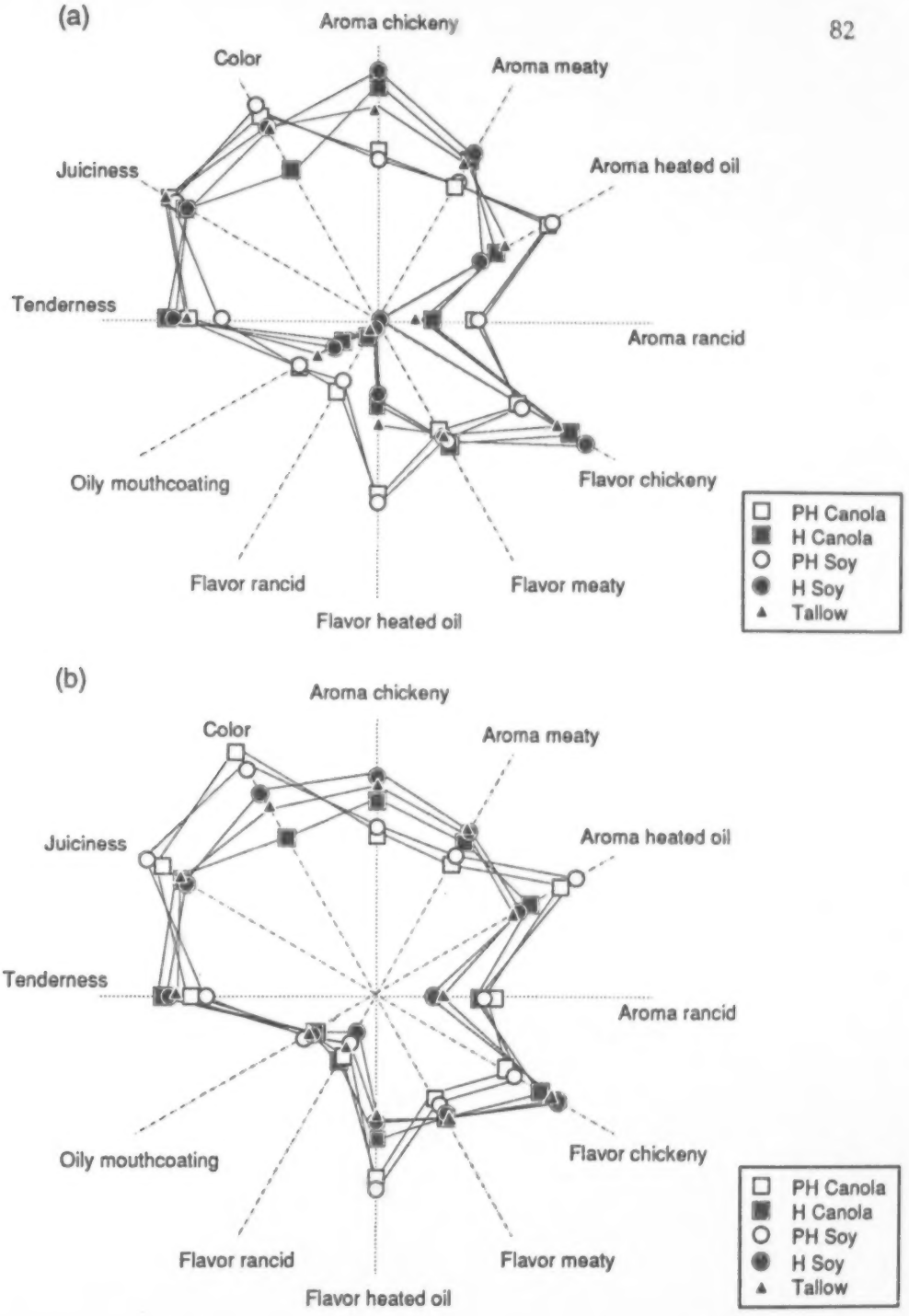


Figure 3. Quantitative descriptive analysis (QDA) diagrams of chicken patties fried in fat treatments evaluated at (a)12 hr and (b) overall treatment means computed across 12 - 48 hr.

Table 8. Means[1] and standard errors for instrumental measurements of fried chicken patties.

Test	Frying Fat Treatment					
	PH[2]Canola	H[2]Canola	PH Soy	H Soy	Tallow	SEM[3]
Hunter "L" value	43.76	44.43	44.77	43.12	45.13	0.66[ns4]
Hunter "a" value	20.33	20.21	19.99	20.10	20.24	0.33[ns]
Hunter "b" value	23.11	23.45	23.87	22.10	23.69	0.45[ns]
Press fluid (%)	47.73	46.65	48.33	47.65	46.76	0.91[ns]
Instron 1[5]	1.35	1.27	1.34	1.32	1.44	0.07[ns]
Instron 2[6]	1.42	1.31	1.39	1.42	1.38	0.05[ns]
Instron 1/g[7]	0.48	0.46	0.49	0.52	0.53	0.03[ns]
Instron 2/g[8]	0.39	0.45	0.38	0.38	0.37	0.03[ns]
Moisture (%)	61.63	61.47	61.87	61.68	61.85	0.25[ns]
Fat content (%)	5.95	5.53	5.72	5.98	5.68	0.17[ns]

[1]Treatment means computed across 12-48 hr of heating.
[2]PH = Partially hydrogenated, H = Hydrogenated.
[3]Standard error of the mean.
[4]Not significant.
[5]Total force of chicken pattie cores with no coating.
[6]Total force of chicken pattie cores with coating.
[7]Force per gram of chicken pattie cores with no coating.
[8]Force per gram of chicken pattie cores with coating.

fried chicken patties is lacking.

Chemical Analysis of Fats Extracted from Chicken Patties

Means and standard errors for chemical analysis of extracted fats from fried chicken patties are presented in Table 9. Chemical analysis of fats extracted from chicken patties are also illustrated in Figure 4. As expected, data for iodine values (IV) of extracted fat from chicken patties cooked in the fat treatments showed significant ($p<0.001$) differences (Table 9). Generally after each 12 hr heating period, IV for extracted PH canola and PH soy fat from patties tended to be similar and significantly higher than the IV for fats extracted from H canola and H soy patties which were the same and higher than extracted tallow. Treatment means over 12-48 hr show that extracted PH fats had similar and higher ($p<0.001$) IV than those found for extracted H fats which were the same and lower in IV than tallow. These differences in extracted fat IV are probably due to the extent of hydrogenation and the polyunsaturated fatty acid content of each frying fat. For each frying fat, IV for the extracted fats tended to remain relatively stable over heating time. A decreasing IV indicates fat degradation due to the loss of polyunsaturated fatty acids with oxidation (Morton, 1988; Waltking et al., 1975). Results indicate that during the entire heating period the frying fats evaluated in the present

Table 9. Means[1] and standard errors for chemical tests of extracted fat from fried chicken patties.

Test	Hr of heating	Frying Fat Treatment					SEM[3]
		PH[2]Canola	H[2]Canola	PH Soy	H Soy	Tallow	
Iodine value (Wijs)	12	99.60[a]	79.57[b]	99.47[a]	76.53[b]	59.87[c]	0.98***
	24	101.00[a]	76.10[c]	94.80[b]	73.93[c]	55.97[d]	1.40***
	36	99.53[a]	78.86[b]	93.90[a]	76.33[b]	54.67[c]	2.73***
	48	99.23[a]	79.30[b]	96.23[a]	74.73[c]	58.43[d]	0.96***
	$\bar{X}$[5]	99.84[a]	79.57[b]	99.47[a]	76.53[b]	59.87[c]	0.79***
Peroxide value (meq/kg)	12	8.02	5.48	7.13	6.28	6.43	0.83[ns4]
	24	5.52	6.17	6.00	5.40	6.39	1.08[ns]
	36	4.68	5.88	6.92	5.97	6.19	0.97[ns]
	48	4.82	5.72	5.53	5.47	6.33	0.65[ns]
	$\bar{X}$	5.76	5.81	6.39	5.78	6.33	0.56[ns]
$E^{1\%}_{1cm}$ (234 nm)	12	11.87[a]	3.81[d]	6.53[b]	4.17[d]	5.81[c]	0.14***
	24	12.07[a]	4.06[d]	6.65[b]	4.02[d]	5.34[c]	0.18***
	36	12.34[a]	3.84[d]	7.02[b]	4.17[d]	5.07[c]	0.25***
	48	12.18[a]	3.89[d]	7.27[b]	4.23[d]	5.39[c]	0.12***
	$\bar{X}$	12.12[a]	3.90[d]	6.86[b]	4.15[d]	5.40[c]	0.10***
$E^{1\%}_{1cm}$ (268 nm)	12	0.82[a]	0.35[c]	0.77[a]	0.32[c]	0.53[b]	0.04***
	24	0.84[a]	0.32[c]	0.79[a]	0.34[c]	0.50[b]	0.04***
	36	0.96[a]	0.39[b]	0.93[a]	0.34[b]	0.40[b]	0.05***
	48	0.96[b]	0.41[d]	1.04[a]	0.42[d]	0.48[c]	0.01***
	$\bar{X}$	0.89[a]	0.36[c]	0.88[a]	0.35[c]	0.48[b]	0.02***

[1]Means are averages of 6 determinations (2 per 3 replicates).
[2]PH = Partially hydrogenated, H = Hydrogenated.
[3]Standard error of the mean.
[4]Not significant.
[5]Treatment mean computed across 0-48 hr of heating.
[abc]Means within the same row sharing a common letter are not significantly different at $p<0.05$.
*** Significant at $p<0.001$.

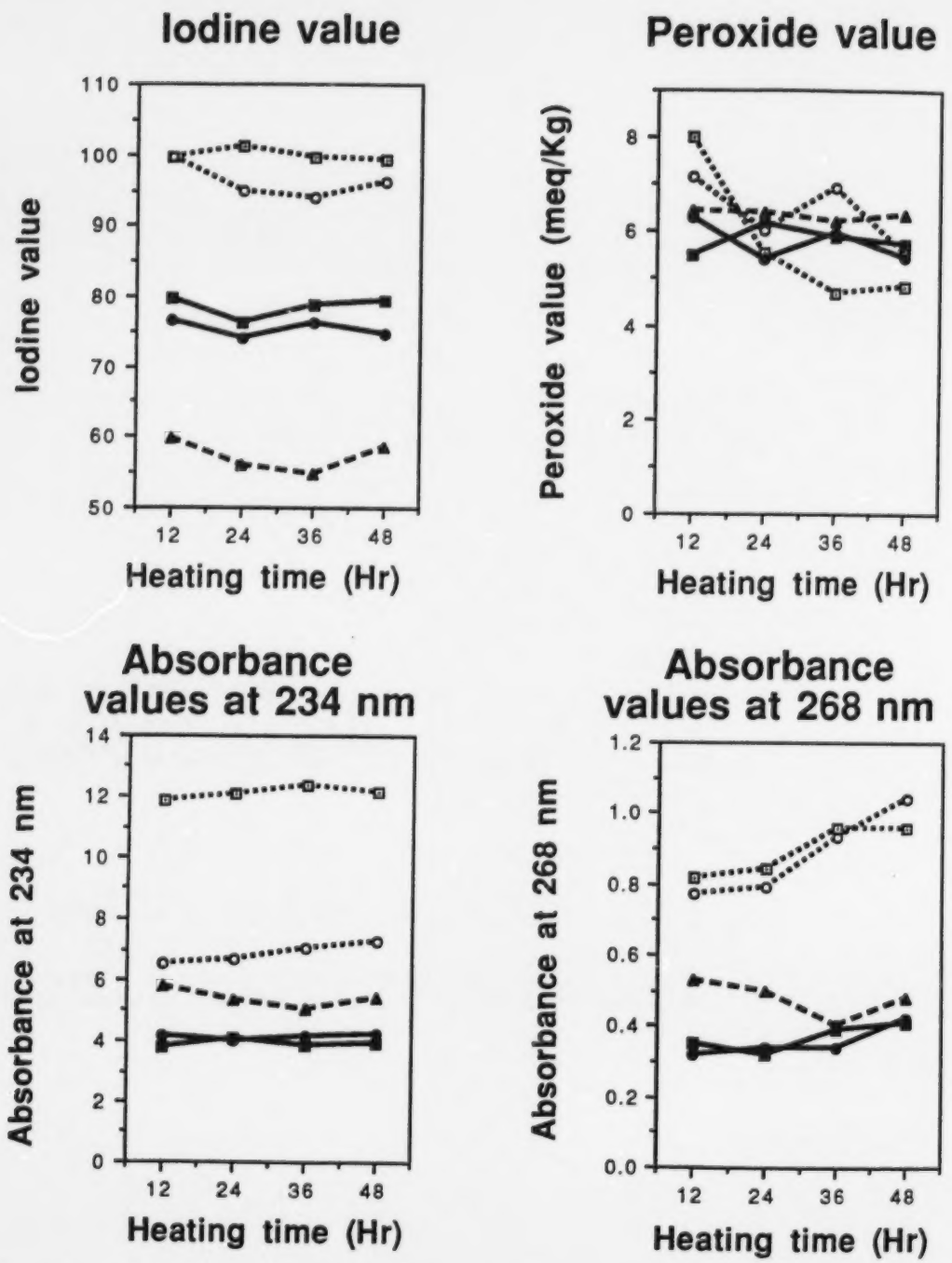


Figure 4. Iodine value, peroxide value and absorbance ($E^{1\%}_{1cm}$) values at 234 and 268 nm of fats extracted from chicken patties fried in heated (177°C) frying fats for 12, 24, 36 and 48 hr.

study had undergone little degradation.

No significant differences in the PV of extracted fats from chicken patties attributable to fat treatment were found. Stevenson et al. (1984b) extracted fats from french fries fried in liquid or solid canola and soybean oils. Data for PV and IV of fats extracted from french fries, reported by Stevenson et al. (1984b) also showed little change during the entire frying period. Conversely, Miller and White (1988a) found significant ($p<0.05$) differences in PV of fat extracted from breadcubes fried in soybean fats heated for 0-40 hr.

In the present study, PV for extracted fats were higher than those determined in the used fats (Table 11). The higher PV for extracted fats compared to used fats may be due to the presence of chicken lipids in the patties and the difficulty in titrating dark colored fat samples. Gwo et al. (1985) noted that used fried chicken fat was too dark in color to determine titration end points used in PV measurements.

Significant ($p<0.001$) differences were found in absorbance values ($E^{1\%}_{1cm}$) at 234 nm of extracted fats with heating time (Table 9). At each 12 hr heating period, the absorbance ($E^{1\%}_{1cm}$) at 234 nm of extracted PH canola was highest, followed by extracted PH soy which differed from extracted tallow, which was also significantly higher in absorbance value ($E^{1\%}_{1cm}$) than extracted H canola and H soy, which were the same. The absorbance ($E^{1\%}_{1cm}$) values at 234 nm of the extracted

fats tended to remain relatively stable over heating time. In the extracted fat data, the high initial absorbance value ($E^{1\%}_{1cm}$) at 234 nm for 12 hr extracted PH canola fat is reflected throughout heating. The high initial absorbance value ($E^{1\%}_{1cm}$) at 234 nm for PH canola may be attributed to its degree of unsaturation (the initial IV).

At 12 and 24 hr of heating, the UV absorbance values ($E^{1\%}_{1cm}$) at 268 nm for extracted PH fats were the same and higher ($p<0.001$) than those for extracted tallow, which in turn differed from values for extracted H fats which were the same and lowest. However after 36 hr, extracted PH canola and PH soy had similar and higher absorbance values ($E^{1\%}_{1cm}$) at 268 nm than those of extracted H fats and tallow which were the same. At 48 hr, the absorbance value ($E^{1\%}_{1cm}$ at 268 nm) for extracted PH soy was highest, followed by that for extracted PH canola which differed from extracted tallow, which was also different from H fats which were the same and had the lowest absorbance value ($E^{1\%}_{1cm}$ at 268 nm). Absorbance values ($E^{1\%}_{1cm}$ at 268 nm) in the extracted fats tended to be similar and low throughout the 48 hr heating period. Overall treatment means show that the PH fats extracted from patties were similar and had the highest ($p<0.001$) absorbance values ($E^{1\%}_{1cm}$ at 268 nm), followed by extracted tallow which differed from both extracted H fats which were the same and lowest.

In the present study, data for UV absorbance values ($E^{1\%}_{1cm}$) at 234 and 268 nm in extracted fats over the 48 hr of heating remained relatively stable. Due to the instability of CD and CT hydroperoxide formation in high temperature frying fats, a decrease in absorbance values ($E^{1\%}_{1cm}$) at 234 and 268 nm after prolonged frying (10 days) has been found (Gwo et al., 1985).

Correlations Between Sensory Data for Chicken Patties and Chemical Data of Fat Extracted from Chicken Patties

In the present study, few significant correlations between extracted fat PV, IV and sensory aroma/flavor data were found (Table 10). However, except for rancid flavor, absorbance values ($E^{1\%}_{1cm}$) at 234 and 268 nm for extracted fats showed significant ($p<0.001$) fair to good correlations with sensory aroma and flavor data (Table 10). As expected, the coefficients between absorbance values ($E^{1\%}_{1cm}$) at 234 and 268 nm and chickeny/meaty aroma/flavor notes are negative while those for absorbance values ($E^{1\%}_{1cm}$) at 234 and 268 nm and heated oil/rancid notes are positive. Reports in the literature on correlations between sensory data for fried food and chemical data for frying fats extracted from fried foods are lacking.

Table 10. Pearson correlation coefficients (r) between sensory aroma and flavor data for chicken patties and chemical data of fat extracted from chicken patties.

TEST	AROMA				FLAVOR			
	Chickeny	Meaty	Heated oil	Rancid	Chickeny	Meaty	Heated oil	Rancid
Peroxide value (meq/Kg)	0.17	0.19	-0.19	-0.21	0.24	0.27*	-0.24*	-0.14
Iodine value	-0.12	-0.06	0.17	0.23	-0.17	-0.08	0.62***	0.04
$E^{1\%}_{1cm}$ (234 nm)	-0.62***	-0.63***	0.64***	0.45***	-0.63***	-0.52***	0.48***	0.07
$E^{1\%}_{1cm}$ (268 nm)	-0.60***	-0.64***	0.47***	0.37***	-0.62***	-0.55***	0.63***	0.03

*, **, *** significant at $p<0.05$, $p<0.01$ and $p<0.001$, respectively.

Initial Fresh Fat Quality

The fatty acid composition (%) of each fat treatment (Table 1 page 8) resembled that published by others (Ackman, 1990). In the present study, PH canola and PH soy contained 2.7% C18:3 and 1.5% C18:3, respectively, while the amount of C18:3 in H canola and H soy was 0.4% and 0.1%. As expected, hydrogenation decreased the level of C18:3 in the hydrogenated vegetable fats.

Data (Table 11) for IV of fresh fats (0 hr of heating), show that the IV for PH canola and PH soy and for H canola and H soy were between 103-100 and 72-68, respectively. The narrow ranges in IV between the PH vegetable fats and H vegetable fats indicate that fats were similar. However, the canola fats tended to be less saturated than their soybean counterparts. As expected, tallow had the lowest IV.

The fresh fats also had low PV and %FFA at 0 hr of heating (Tables 11 and 12). The initial PV of each fat treatment was less than or equal to 1 meq/Kg and the initial %FFA were well below the range of 0.05-0.08%. A PV of 1 meq/Kg and %FFA values between 0.05-0.08% are common analytical specifications for fresh deep fat frying fats (Stevenson et al., 1984a).

Table 11. Means[1] and standard errors for iodine value, peroxide value and p-anisidine value of used fat.

Test	Hr of heating	Frying Fat Treatment					
		PH[2]Canola	H[2]Canola	PH Soy	H Soy	Tallow	SEM[3]
Iodine Value (Wijs)	0	103.08^{a}	71.91^{c}	100.61^{b}	68.62^{d}	45.31^{e}	0.69***
	12	104.83^{a}	73.50^{b}	103.96^{a}	71.10^{b}	45.78^{c}	0.85***
	24	104.88^{a}	73.48^{c}	101.77^{b}	70.75^{d}	45.26^{e}	0.43***
	36	105.07^{a}	73.31^{c}	102.43^{b}	71.30^{d}	45.08^{e}	0.49***
	48	104.45^{a}	73.62^{c}	101.90^{b}	71.41^{d}	45.36^{e}	0.49***
	$\bar{X}$[4]	104.46^{a}	73.16^{c}	102.13^{b}	70.64^{d}	45.36^{e}	0.32***
Peroxide Value (meq/Kg)	0	0.53^{b}	0.62^{b}	1.02^{a}	0.62^{b}	0.22^{c}	0.04***
	12	1.19	1.51	1.42	1.93	1.91	0.16[ns5]
	24	1.27^{b}	1.35^{b}	1.50^{b}	1.62^{b}	1.99^{a}	0.11*
	36	1.25^{c}	1.34^{c}	1.42^{bc}	1.64^{ab}	1.86^{a}	0.07**
	48	1.66	1.12	1.52	1.53	1.32	0.14[ns]
	$\bar{X}$	1.18	1.19	1.37	1.47	1.46	0.08[ns]
p-Anisidine value (350 nm)	0	1.34	1.34	1.63	2.08	1.47	0.29[ns]
	12	19.82^{b}	9.45^{d}	28.74^{a}	8.28^{e}	12.92^{c}	0.35***
	24	28.68^{b}	12.53^{d}	37.30^{a}	10.17^{d}	15.92^{c}	0.94***
	36	28.21^{b}	12.19^{d}	38.37^{a}	10.26^{d}	15.94^{c}	0.88***
	48	28.52^{b}	10.24^{d}	38.91^{a}	10.02^{d}	15.57^{c}	0.97***
	$\bar{X}$	21.32^{b}	9.15^{d}	28.99^{a}	8.16^{d}	12.36^{c}	0.37***

[1]Means are averages of 6 determinations (2 per 3 replicates).
[2]PH = Partially hydrogenated, H = Hydrogenated.
[3]Standard error of the mean.
[4]Treatment mean computed across 0-48 hr of heating.
[5]Not significant.
[abcde]Means within the same row sharing a common letter are not significantly different at $p<0.05$. *, **, *** Significant at $p<0.05$, $p<0.01$ and $p<0.001$, respectively.

Table 12. Means[1] and standard errors for free fatty acids and absorbance ($E^{1\%}_{1cm}$) values at 234 and 268 nm of used fat.

Test	Hr of heating	Frying Fat Treatment					
		PH[2]Canola	H[2]Canola	PH Soy	H Soy	Tallow	SEM[3]
% Free fatty acid (715 nm)	0	0.00	0.01	0.00	0.00	0.01	0.00^{ns}
	12	0.06^{b}	0.10^{a}	0.07^{b}	0.08^{ab}	0.08^{ab}	0.01^{**}
	24	0.13^{b}	0.18^{a}	0.12^{b}	0.15^{ab}	0.16^{ab}	0.01^{*}
	36	0.25	0.30	0.21	0.25	0.25	0.02^{ns}
	48	0.30^{b}	0.43^{a}	0.30^{b}	0.37^{ab}	0.38^{ab}	0.02^{**}
	$\bar{X}$[4]	0.15^{cd}	0.20^{a}	0.14^{d}	0.17^{bc}	0.18^{b}	0.01^{***}
$E^{1\%}_{1cm}$ (234 nm)	0	14.66^{a}	3.00^{d}	6.00^{b}	4.00^{c}	6.00^{b}	0.15^{***}
	12	18.67^{a}	3.67^{d}	8.33^{b}	4.33^{d}	6.67^{c}	0.45^{***}
	24	17.00^{a}	3.67^{d}	8.67^{b}	4.00^{d}	6.33^{c}	0.31^{***}
	36	17.00^{a}	3.67^{e}	9.00^{b}	4.67^{d}	6.67^{c}	0.22^{***}
	48	17.00^{a}	4.67^{c}	8.67^{b}	3.67^{d}	5.33^{c}	0.59^{***}
	$\bar{X}$	16.86^{a}	3.73^{d}	8.13^{b}	4.13^{d}	6.20^{c}	0.19^{***}
$E^{1\%}_{1cm}$ (268 nm)	0	40.67	63.67	83.00	35.33	65.33	15.35^{ns5}
	12	33.33	60.67	44.33	71.00	44.00	13.70^{ns}
	24	73.33	44.00	49.67	54.67	33.33	14.12^{ns}
	36	61.67	84.33	58.00	41.33	32.67	15.56^{ns}
	48	33.67	5.33	66.00	33.33	65.67	13.14^{ns}
	$\bar{X}$	48.53	51.60	60.20	47.13	48.20	6.46^{ns}

[1]Means are averages of 6 determinations (2 per 3 replicates).
[2]PH = Partially hydrogenated, H = Hydrogenated.
[3]Standard error of the mean.
[4]Treatment mean computed across 0-48 hr of heating.
[5]Not significant.
[abcde]Means within the same row sharing a common letter are not significantly different at $p<0.05$. *, **, *** Significant at $p<0.05$, $p<0.01$ and $p<0.001$, respectively.

Chemical Analysis of Used Frying Fats

Means and standard errors for IV, PV, AV, %FFA and absorbance values ($E^{1\%}_{1cm}$) at 234 and 268 nm of used frying fats are presented in Tables 11 and 12. Chemical analysis of used frying fats is also illustrated in Figures 5 and 6. In the present study, the fat treatments with varying levels of hydrogenation showed significant ($p<0.001$) differences in IV (Table 11). Canola fats were more ($p<0.001$) unsaturated than the soybean fats and this small but significant difference may contribute to some differences found in the instrumental/chemical and sensory findings noted in this thesis. Except after 12 hr of heating, IV for all fat treatments were significantly ($p<0.001$) different from each other. At 12 hr, PH canola and PH soy had similar and higher IV than the H fats which were also higher in IV than the tallow. Data for IV show all frying fats remained relatively stable over the entire frying period. Examining heated soybean oil stability, Chu (1991) found IV measurements to be a reliable indicator of frying fat quality and reported high ($p<0.001$) correlations with other chemical tests.

Although the initial PV of the frying fats differed significantly, the significant differences in these low values (<1 meq/Kg) are not of practical importance. At 12 hr of heating, the PV of all fats increased markedly (0.40-1.79

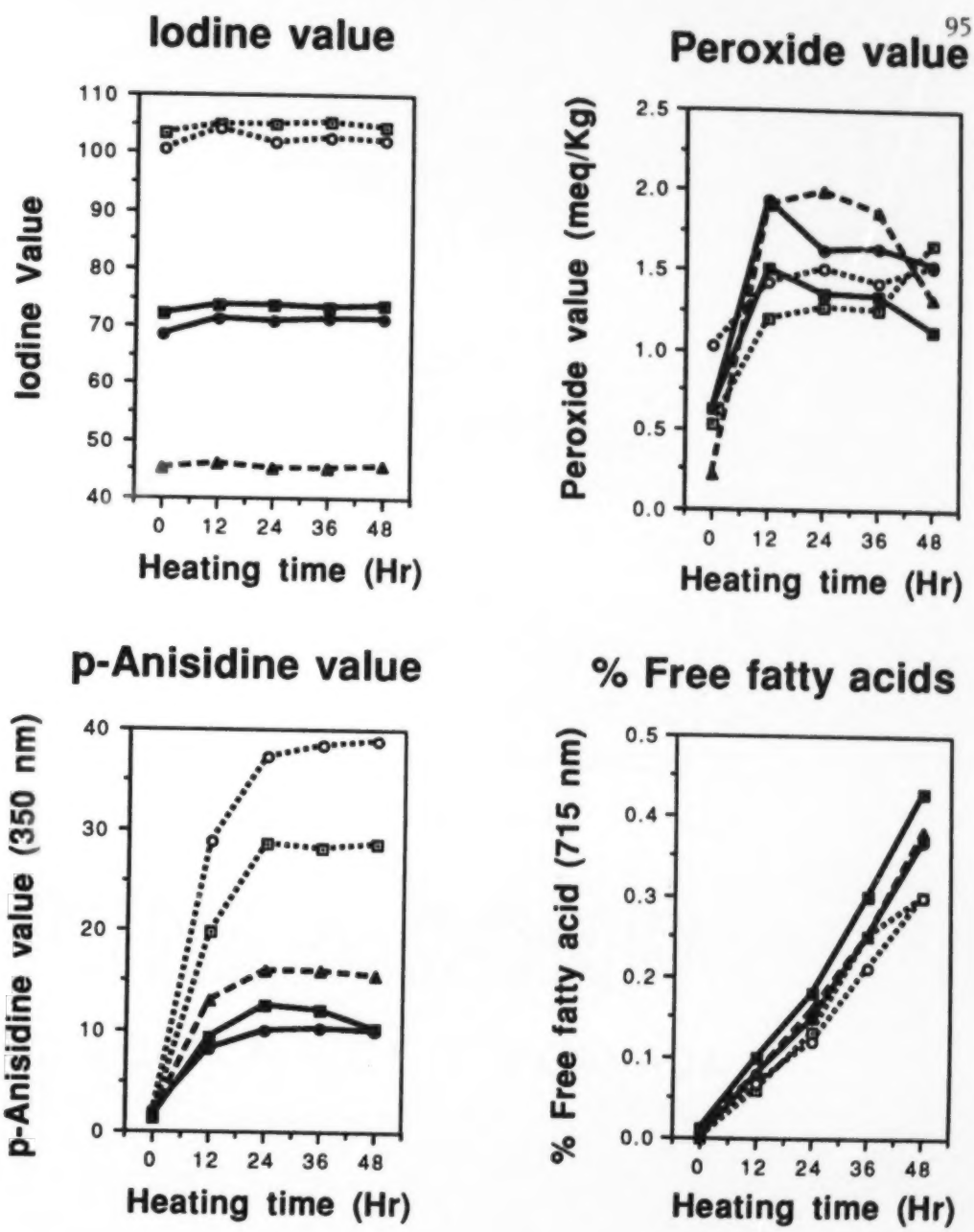


Figure 5. Iodine value, peroxide value, p-anisidine value and free fatty acids of used frying fats heated (177°C) for 0, 12, 24, 36 and 48 hr.

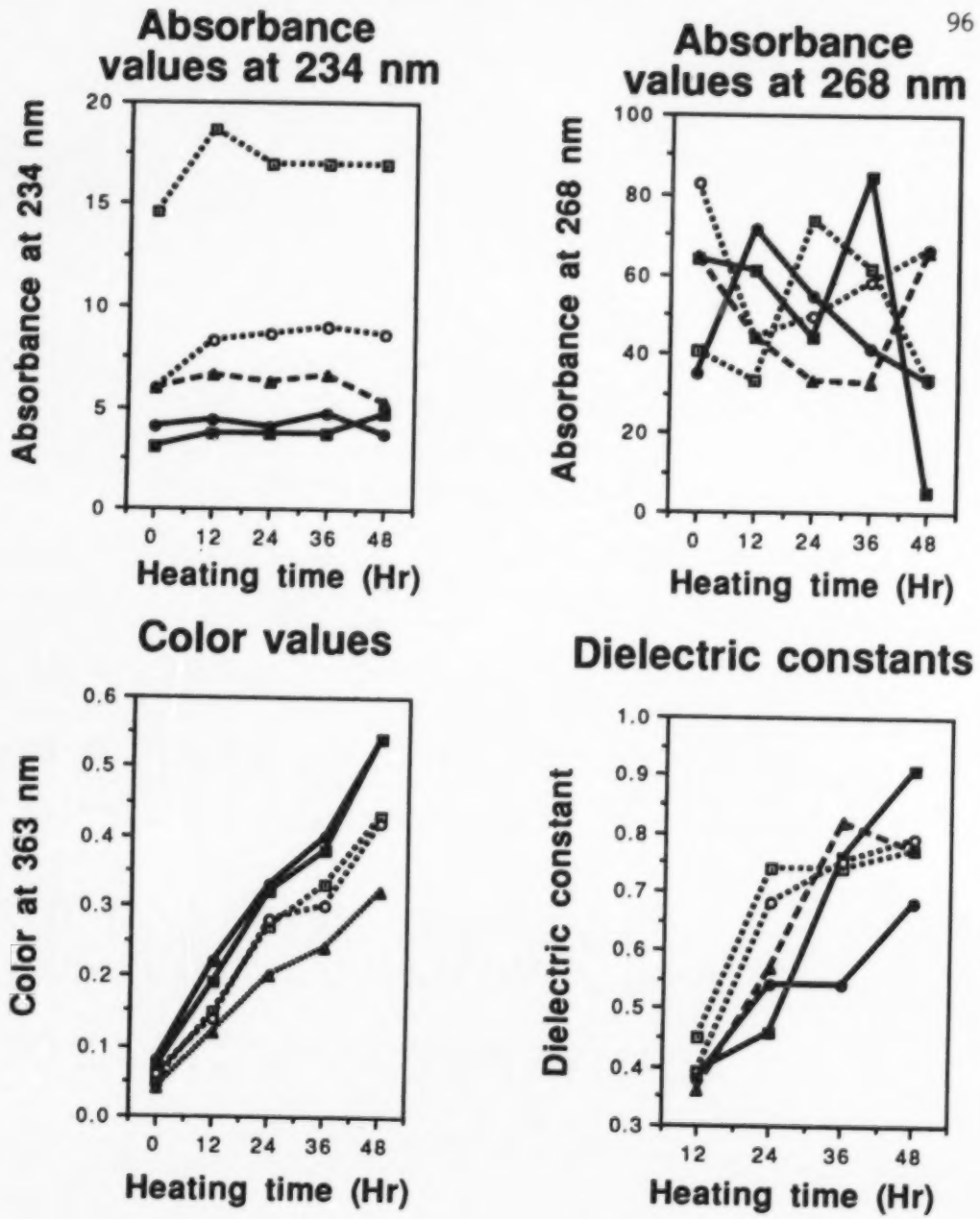


Figure 6. Absorbance ($E^{1\%}_{1cm}$) values at 234 and 268 , color and dielectric constants of used frying fats heated (177°C) frying fats for 12, 24, 36 and 48 hr.

meq/Kg), but no differences in PV were found among fat treatments. At 24 hr, except for tallow which had the highest ($p<0.05$) PV, all other fats had the same PV. At 36 hr, the PV for tallow remained high but did not differ from H soy which in turn was similar to the PV of PH soy. The PV of PH soy was similar to the low values of both PH canola and H canola after 36 hr of frying. After prolonged heating (48 hr), no differences in PV were found among the fats. Overall treatment means across 0-48 hr also show no differences in PV among the fat treatments.

In the current study, except for the H fats, PV for all treatment fats tended to increase markedly from 0 hr to 24 hr and then decrease or remain stable with additional frying (Figure 5). The PV for H fats increased during the first 12 hr heating period but decreased with additional frying from 24 to 48 hr. Other researchers (Wu and Chen, 1992; Zhang and Addis, 1990; Gwo et al., 1985; Paradis and Nawar, 1981) have reported PV similar to those obtained in the present study. Paradis and Nawar (1981) determined the PV in pourable high stability shortening samples from local restaurants frying poultry, vegetables and seafood. These researchers (Paradis and Nawar, 1981) noticed a sharp increase in PV of fats from days 0 to 3, followed by a decline in PV with further frying on day 4. Zhang and Addis (1990) noted a non-linear relationship between PV and frying time for french fries cooked in tallow for 122 hr. In their (Zhang and Addis, 1990)

study, PV increased with frying time to a maximum at 80 hr then declined with further frying. Gwo et al. (1985), using PH soy oil and animal-vegetable blends, found PV declined on the sixth of ten frying days. Since hydroperoxides are unstable at high frying temperatures (Fritsch, 1981), the decrease in PV with prolonged frying would be expected (Zhang and Addis, 1992; 1990; Gwo et al., 1985; Smouse, 1985). Findings of the present study and those of others (Zhang and Addis, 1990; Miller and White, 1988a; Gwo et al., 1985; Fritsch, 1981; Paradis and Nawar, 1981) suggest that use of PV may not be a good indicator for measuring frying fat deterioration.

The AV of fresh fats at 0 hr of heating (Table 11), showed that the fat treatments were similar initially. However at each frying time, significant ($p<0.001$) differences were found in AV among the fat treatments. At 12 hr, AV for all fat treatments differed significantly ($p<0.001$); PH soy had the highest AV, followed by PH canola, tallow, H canola and H soy, respectively. With further frying (24, 36, 48 hr) and over the 0-48 hr, PH soy had the highest AV, followed by PH canola and then tallow, which all differed ($p<0.001$) from the H fats which were similar and had the lowest AV. The low AV (10.24-10.02) of the H canola and H soy treatments throughout the frying periods indicate borderline recommended values for fresh fats. Recommended AV for initial fresh

frying fats are between 1.0-10.0 (Stevenson et al., 1984a). As expected, these low AV in H vegetable fats show that after hydrogenation, the vegetable fats were more stable than their PH counterparts and tallow. In the current study, AV in all fats increased markedly at 0-24 hr of heating and levelled off with further heating (Figure 5).

Except for H fats which tended to be the same, AV for all fat treatments were significantly ($p<0.001$) different. Since AV is a measure of aldehyde production by oxidation (IUPAC, 1987; Smouse, 1985) and is fat specific (Patterson, 1989), differences in AV among treatment fats are expected. List et al. (1974) reported lower AV for H soybean fat than for unhydrogenated soybean oil. Results of the present study support the findings of List et al. (1974). Comparisons of AV for PH and H heated vegetable fats are lacking.

Data for initial (0 hr) %FFA content of the frying fats did not differ. These values ranging from zero to 0.01% indicate that all fats were of good initial quality (Table 12). At 12, 24 and 48 hr of heating, %FFA in all treatments increased and H canola had the highest ($p<0.05$; $p<0.01$) %FFA but did not differ from both H soy and tallow which were also the same as the PH fats with the lowest %FFA. After 36 hr of heating, %FFA in all fat treatments increased; however, no differences in %FFA were found among the fats. Overall treatment means indicate that %FFA in H canola was highest

($p<0.001$), followed by tallow and H soy which were the same, but H soy did not differ from PH canola which was also like PH soy that had the lowest %FFA content. After 48 hr of frying, the %FFA in treatment fats reached a value of 0.43 much lower than 1%, the recommended level for discarding used frying fats (Firestone et al., 1991; Stevenson et al., 1984a; Billek et al., 1978). Thus in the present study, %FFA data show that frying fats exhibited minimum thermal deterioration.

Hawrysh et al. (1991) reported no significant differences in %FFA in the heated canola and soybean fats in their french fry study. In addition, a maximum %FFA value of 0.51, similar to that found in the present study, was reached after 24 hr of heating (Hawrysh et al., 1991). Stevenson et al. (1984b) reported %FFA levels of greater than 1% with both lightly and fully hydrogenated canola and soybean fats with 37.5 hr of heating. Since FFA can be produced by both hydrolysis and oxidative processes in heated frying fats, the %FFA test has been suggested by some researchers (Croon et al., 1986; Stevenson et al., 1984a; Fritsch, 1981) to be an unreliable method to determine frying fat deterioration. Since rates of hydrolysis and oxidation vary due to frying conditions within each frying operation (Stevenson et al., 1984a), this may explain the difficulty of comparing %FFA data among studies.

At each heating time, significant ($p<0.001$) differences among fat treatments were found for UV absorbance values ($E^{1\%}_{1cm}$

at 234 nm); however, none were determined for absorbance ($E^{1\%}_{1cm}$) at 268 nm (Table 12). The significant differences in absorbance values ($E^{1\%}_{1cm}$) at 234 nm initially (0 hr) are primarily due to the degree of hydrogenation of the fat treatments and these differences in absorbance values are reflected throughout heating for each fat treatment.

Initially (0 hr), PH canola had the highest absorbance ($E^{1\%}_{1cm}$) at 234 nm, followed by PH soy and tallow which were similar but different ($p<0.001$) from H soy, which also differed from H canola with the lowest absorbance at 234 nm. At 12 and 24 hr of heating, PH canola had a significantly higher absorbance ($E^{1\%}_{1cm}$) at 234 nm than PH soy which also differed from tallow. However, both H canola and H soy had a similar low absorbance. After 36 hr, all fat treatments differed in absorbance at 234 nm. After 48 hr, PH canola had the highest absorbance value ($E^{1\%}_{1cm}$) at 234 nm followed by PH soy which was higher than both H canola and tallow which were the same and also differed from H soy. Overall treatment means show that except for H fats which were similar and lowest in absorbance values ($E^{1\%}_{1cm}$) at 234 nm, all treatment fats differed ($p<0.001$).

Compared to initial values for fresh fats, UV absorbance data ($E^{1\%}_{1cm}$ at 234 nm), remained relatively stable throughout heating (Figure 6). Generally little deterioration occurred in each of the fats over the entire heating period, suggesting that the fats were relatively stable after 48 hr of heating.

Careful examination of the effects of frying time within each fat treatment generally indicated a gradual increase in absorbance ($E^{1\%}_{1cm}$) at 234 nm in the initial 12 hr of heating, followed by a levelling off or slight decrease in absorbance with further frying (Figure 6), resembling that noted with PV data (Figure 5). These similarities in absorbance ($E^{1\%}_{1cm}$) at 234 nm and PV data for the heated fats are expected as both tests rely on the production of primary oxidation products of frying fat deterioration (White, 1991). The low absorbance values ($E^{1\%}_{1cm}$) at 234 nm for the H canola and H soy may be explained by the low polyunsaturated fatty acid composition (Table 1 page 8). As expected tallow (a saturated fat) showed low absorbance values ($E^{1\%}_{1cm}$) at 234 nm over the 48 hr of frying. The low absorbance values ($E^{1\%}_{1cm}$) at 234 nm for the H vegetable fats in the present study indicate that hydrogenation was effective in increasing fat oxidative stability during deep fat frying.

In used french fry commercial frying fat, Gwo et al. (1985) found an initial increase in absorbance ($E^{1\%}_{1cm}$) at 234 nm up to 2 days followed by a decline after prolonged frying (10 days). These researchers (Gwo et al., 1985) attributed the decline in absorbance ($E^{1\%}_{1cm}$) at 234 nm to the further breakdown of unstable CD hydroperoxides into other degradation products which may not be detected at 234 nm.

Absorbance values ($E^{1\%}_{1cm}$) at 268 nm for the frying fats over the 48 hr of heating showed large variations (Figure 6).

No similarities in absorbance ($E^{1\%}_{1cm}$) data for either the PH or H vegetable fats were found (Table 12). Thus the absorbance ($E^{1\%}_{1cm}$) at 268 nm was not a useful measure of thermal degradation of the fats.

Means and standard errors for color and dielectric constants are presented in Table 13. At each heating time, small but significant differences in color among the fat treatments were found. As expected with continued frying, all fats darkened due to fat degradation (Figure 6). At 0 hr, H canola, PH soy and H soy were similar and darker ($p<0.001$) in color than PH canola which was also darker than tallow. At 12 hr of heating, the H fats were darker ($p<0.001$) in color than the PH fats and tallow which were the same. After 24 hr, the H fats remained darker ($p<0.05$) in color than tallow; however the H fats were similar to the PH fats which also did not differ in color from tallow. As frying progressed to 36 and 48 hr, the H fats were similar and darker ($p<0.001$) in color than both the PH fats which in turn differed from tallow which had the lightest color. In the present study, the small but significant color differences found among fat treatments appear to be due to the initial color of each fat.

Mazza and Qi (1992) investigated after-cooking darkening in H canola fat used to fry french fries. The researchers (Mazza and Qi, 1992) found that the color index of H canola fat increased with heating time, indicating that the quantity

Table 13. Means[1] and standard errors for color and dielectric constant of used fats.

Test	Hr of heating	Frying Fat Treatment					
		PH[2]Canola	H[2]Canola	PH Soy	H Soy	Tallow	SEM[3]
Color (363 nm)	0	0.05[b]	0.07[a]	0.06[a]	0.08[a]	0.04[c]	0.00***
	12	0.15[b]	0.19[a]	0.14[b]	0.22[a]	0.12[b]	0.01***
	24	0.27[ab]	0.32[a]	0.28[ab]	0.33[a]	0.20[b]	0.02*
	36	0.33[b]	0.38[a]	0.30[b]	0.40[a]	0.24[c]	0.02***
	48	0.43[b]	0.54[a]	0.42[b]	0.54[a]	0.32[c]	0.02***
	$\bar{X}$[4]	0.25[b]	0.30[a]	0.24[b]	0.31[a]	0.18[c]	0.01***
Dielectric constant[6]	12	0.45	0.39	0.39	0.38	0.36	0.06[ns5]
	24	0.74	0.46	0.68	0.54	0.57	0.08[ns]
	36	0.74	0.76	0.75	0.54	0.82	0.08[ns]
	48	0.77	0.91	0.79	0.68	0.77	0.04[ns]
	$\bar{X}$	0.67	0.63	0.65	0.54	0.63	0.04[ns]

[1]Means are averages of 6 determinations (2 per 3 replicates).
[2]PH = Partially hydrogenated, H = Hydrogenated.
[3]Standard error of the mean.
[4]Treatment means computed across 0-48 or 12-48 hr.
[5]Not significant.
[6]Means of 3 determinations (1 per 3 replicates).
[abcde]Means within the same row sharing a common letter are not significantly different at $p<0.05$
*, *** Significant at $p<0.05$ and $p<0.001$, respectively.

of the decomposition products formed in the heated frying fat increased the UV absorption on which color measurements were based. Gwo et al. (1985) studied color development in commercial deep frying shortening used to fry chicken and french fries over a 10 day period and reported increased oil darkening with days of frying. In addition to accumulation of non volatile decomposition products during frying, darkening of fats during frying was attributed to ingredients in the batter or coatings used, resulting in caramelization, carbonization of starch from wheat flour and Maillard browning reactions (Gwo et al., 1985).

At each frying time, the dielectric constants (DC) of fats determined with the Foodoil sensor showed no significant differences among the fat treatments (Table 13). Although no differences in DC were found among fats in the present study, the DC of all fats generally increased with heating time to a maximum value of 0.91 (Figure 6). A DC of 4.0 is commonly used as the indicator for discarding a frying fat (Fritsch, 1981). Thus all of the frying fats in the current study were very stable after 48 hr of use.

The DC data obtained for tallow in the present study are similar to that of Zhang and Addis (1990) who reported a DC value of 1.24 and a %FFA value of 0.23 for tallow after 48 hr of frying. Comparing the frying characteristics of H soybean shortening and soybean oil heated 32 hr (190°C), Fritsch et al. (1979) reported much "lower" DC values for H soybean

shortening than for the unhydrogenated oil. Since Foodoil sensor readings are a measure of frying oil degradation (El-Shami et al., 1992; White, 1991; Augustin et al., 1987; Stevenson et al., 1984a; Fritsch, 1981; Fritsch et al., 1979), H frying fats with improved oxidative stability will produce lower DC values than unhydrogenated oil (Fritsch et al., 1979). Research comparing the DC values of PH and H vegetable fats with thermal stabilty during frying is lacking.

Instrumental Analysis of Used Frying Fats

Data for smoke points (Table 14) of fresh (0 hr) and used fats show significant differences throughout heating times. Initially (0 hr), smoke points of all fats were above 200°C, a requirement for fresh frying fats (Stevenson et al., 1984a). At 0 hr, both PH canola and PH soy had similar and higher ($p<0.01$) smoke points than the H fats and tallow which were the same. At 12 hr, except for PH soy which was significantly ($p<0.05$) higher than H canola, all treatment fats had similar smoke points. After 24 hr of heating, the PH fats were the same and had higher ($p<0.05$) smoke points than H canola, but the PH fats did not differ from H soy and tallow, which were also similar to H canola. After 36 hr, the smoke point of PH soy was highest ($p<0.01$) but the same as that of PH canola, which in turn did not differ from the H fats and tallow which had similar smoke points. After prolonged frying (48 hr),

Table 14. Means[1] and standard errors for instrumental measurements of used fats.

Test	Hr of heating	Frying Fat Treatment					
		PH[2]Canola	H[2]Canola	PH Soy	H Soy	Tallow	SEM[3]
Smoke point (°C)	0	223.00^{a}	212.86^{b}	223.43^{a}	207.76^{b}	211.43^{b}	2.46**
	12	202.10^{ab}	195.43^{b}	206.10^{a}	202.10^{ab}	201.07^{ab}	1.81*
	24	188.60^{a}	175.63^{b}	188.10^{a}	184.07^{ab}	178.77^{ab}	2.39*
	36	171.97^{ab}	164.97^{b}	175.63^{a}	166.30^{b}	166.63^{b}	1.86*
	48	166.86^{a}	156.96^{b}	167.43^{a}	158.87^{b}	157.63^{b}	1.70**
	$\bar{X}$[4]	190.51^{a}	181.17^{b}	192.14^{a}	183.82^{b}	183.11^{b}	1.47***
Viscosity (cps)	0	23.51^{c}	25.35^{a}	21.09^{e}	25.05^{b}	22.88^{d}	0.05***
	12	24.03^{b}	25.74^{a}	22.21^{c}	25.81^{a}	23.86^{b}	0.17***
	24	24.40^{b}	25.99^{a}	22.79^{c}	26.01^{a}	24.12^{b}	0.16***
	36	24.90^{b}	26.35^{a}	22.75^{d}	26.18^{a}	24.26^{c}	0.11***
	48	25.23^{c}	26.55^{a}	23.02^{e}	26.21^{b}	24.29^{d}	0.09***
	$\bar{X}$	24.41^{b}	25.99^{a}	22.37^{d}	25.85^{a}	23.88^{c}	0.07***

[1]Means are averages of 9 determinations (3 per 3 replicates).
[2]PH = Partially hydrogenated, H = Hydrogenated.
[3]Standard error of the mean.
[4]Treatment means computed across 0-48 hr of heating.
[abcde]Means with the same row sharing a common letter are not significantly different at $p<0.05$.
*, **, *** Significant at $p<0.05$, $p<0.01$ and $p<0.001$, respectively.

both PH fats had higher ($p<0.01$) smoke points than the H fats and tallow which did not differ. Overall means reflect initial (fresh fat) smoke point values; PH fats had higher ($p<0.001$) smoke points than the H fats and tallow which were the same. These initial differences in smoke points among the fat treatments are reflected in each of the 12 hr heating periods. As expected, the smoke point for each of the fats decreased with heating time.

After 36 hr of frying, the smoke points for the H fats and tallow were below 170°C, and after 48 hr, all fat smoke points were below 170°C. A smoke point of 170°C is commonly used as the criteria for discarding used frying fats in some European countries (Firestone et al., 1991; Stevenson et al., 1984b). Smoke point data for fats in the present study are shown in Figure 7 and are similar to those of Stevenson et al. (1984b) who reported smoke points below 170°C after 15-20 hr of frying for liquid or solid canola and soybean fats.

At each heating time, small but significant ($p<0.001$) differences in viscosity were evident among treatment fats (Table 14). The initial (0 hr) differences in viscosity among the fats are generally reflected in subsequent frying periods. At 0 and 48 hr of heating, H canola had the highest ($p<0.001$) viscosity followed by H soy, PH canola, tallow and PH soy, respectively. After 12 and 24 hr, the viscosity of both H fats was higher ($p<0.001$) than those of PH canola and tallow

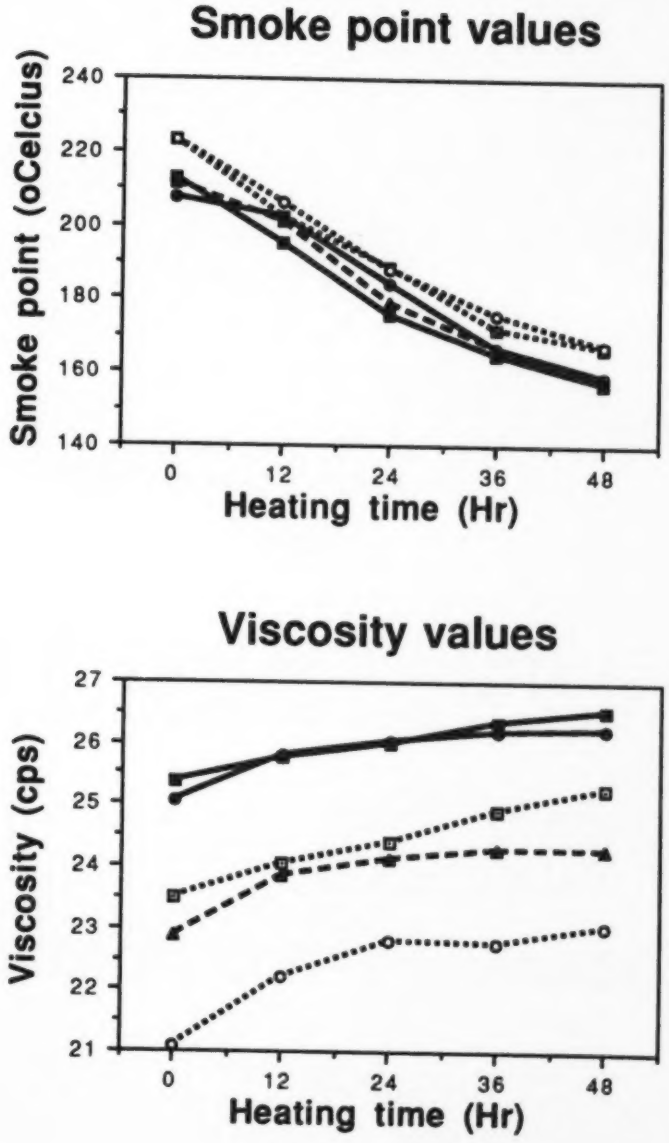


Figure 7. Smoke point and viscosity values of heated (177°C) frying fats for 0, 12, 24, 36 and 48 hr.

which were the same and also differed from PH soy. At 36 hr of heating, differences in viscosity similar to those noted at 12 and 24 hr were detected, but the viscosity of PH canola differed significantly ($p<0.001$) from tallow. Overall treatment means across 0-48 hr show viscosity data to be similar to those found at 36 hr of heating.

In the present study, the viscosity of each fat tended to increase slowly as frying time continued (Figure 7), indicating polymerization to be a factor in frying fat degradation (White, 1991; Guitierrez Gonzalez-Quijano et al., 1988). The accumulation of high molecular weight compounds formed by polymerization caused the increased viscosity in the heated fats (Guitierrez Gonzalez-Quijano et al., 1988; Stevenson et al., 1984a, 1984b; Fritsch, 1981). Bracco et al. (1981), using heated palm oil liquid fractions (0-124 hr), reported viscosity data as exponential-like with heating time. The small increases found in viscosity in the present study, show that each frying fat was stable throughout the heating period.

Gas Chromatographic Analysis of Volatiles in Heated Fats

During frying many volatile constituents were formed in the fats. However not all volatiles produced are important to the flavor of frying fats (Miller and White, 1988b). Tables 15 and 16 show selected volatiles found in the heated fats in

Table 15. Means[1] and standard errors for gas chromatographic analysis of volatiles in heated fats.

Volatile compound	Hr of heating	Frying Fat Treatment					
		PH[2] Canola	H[2] Canola	PH Soy	H Soy	Tallow	SEM[3]
Pentane	0	1.43[a]	0.76[d]	1.17[b]	0.91[c]	1.21[b]	0.03***
	12	2.65[a]	1.37[c]	2.16[b]	1.22[c]	1.43[c]	0.14***
	24	2.66[a]	1.34[b]	2.44[a]	1.22[b]	1.37[b]	0.08***
	36	2.52[a]	1.09[c]	2.25[b]	1.07[c]	1.21[c]	0.05***
	48	2.65[a]	1.37[b]	2.39[a]	1.13[b]	1.26[b]	0.12***
	$\bar{X}$[4]	2.38[a]	1.18[c]	2.08[b]	1.11[c]	1.29[c]	0.08***
Hexanal	0	0.05	0.01	0.00	0.00	0.06	0.00[ns5]
	12	1.82[b]	1.37[b]	3.29[a]	1.62[b]	1.75[b]	0.12***
	24	1.91[b]	1.31[b]	2.96[a]	1.82[b]	1.87[b]	0.22**
	36	1.88[b]	1.40[b]	3.15[a]	1.63[b]	1.67[b]	0.15***
	48	2.19[b]	1.18[d]	3.35[a]	1.63[c]	1.75[c]	0.12***
	$\bar{X}$	1.57[b]	1.05[d]	2.55[a]	1.34[c]	1.42[bc]	0.06***
2-Heptenal	0	0.00	0.11	0.00	0.02	0.00	0.05[ns]
	12	2.74[ab]	1.53[b]	3.71[a]	2.07[b]	1.78[b]	0.38*
	24	2.92[b]	1.50[d]	4.91[a]	1.91[c]	1.68[d]	0.07***
	36	2.87[b]	1.29[d]	4.99[a]	1.98[c]	1.49[d]	0.15***
	48	2.88[b]	1.15[d]	4.74[a]	1.85[c]	1.57[c]	0.11***
	$\bar{X}$	2.28[b]	1.12[d]	3.67[a]	1.57[c]	1.30[d]	0.09***
2,4-Heptadienals	0	0.06	0.04	0.06	0.15	0.05	0.03[ns]
	12	4.04[a]	1.53[c]	2.82[b]	0.47[d]	2.13[bc]	0.29***
	24	4.19	1.19	2.40	2.19	2.20	0.78[ns]
	36	4.04[a]	2.09[ab]	2.46[a]	0.33[b]	1.91[ab]	0.47**
	48	3.67[a]	0.95[c]	2.25[b]	0.44[c]	1.99[b]	0.16***
	$\bar{X}$	3.20[a]	1.16[cd]	2.00[b]	0.72[d]	1.66[bc]	0.21*

[1]Means are averages of 6 determinations (2 per 3 replicates) expressed in parts per million.
[2]PH = Partially hydrogenated, H = Hydrogenated.
[3]Standard error of the mean.
[4]Treatment mean computed across 0-48 hr of heating.
[5]Not significant.
[abcd]Means within the same row sharing a common letter are not significantly different at $p<0.05$. *, **, *** Significant at $p<0.05$, $p<0.01$ and $p<0.001$, respectively.

Table 16. Means[1] and standard errors for gas chromatographic analysis of volatiles in heated fats.

Volatile compound	Hr of heating	Frying Fat Treatment					
		PH[2]Canola	H[2]Canola	PH Soy	H Soy	Tallow	SEM[3]
2-Octenal	0	0.00	0.00	0.01	0.07	0.02	0.02[ns4]
	12	2.83[c]	2.76[c]	4.36[a]	3.70[b]	2.59[c]	0.18***
	24	3.12[b]	2.73[b]	4.32[a]	3.37[b]	2.63[b]	0.17***
	36	3.20[b]	2.34[b]	4.49[a]	3.44[b]	2.54[c]	0.17***
	48	3.07[b]	2.05[d]	4.33[a]	3.43[b]	2.62[c]	0.11***
	$\bar{X}$[5]	2.44[c]	1.97[d]	3.50[a]	2.80[b]	2.08[d]	0.07***
2,4-Decadienals	0	0.27[ab]	0.21[ab]	0.69[a]	0.15[b]	0.23[ab]	0.11*
	12	1.44[b]	0.59[c]	2.68[a]	0.79[bc]	0.85[bc]	0.17***
	24	1.17	0.56	2.77	0.87	1.94	0.50[ns]
	36	1.29[b]	0.61[b]	2.58[a]	1.35[b]	0.79[b]	0.23**
	48	1.20[ab]	0.40[b]	4.56[a]	1.24[ab]	0.94[ab]	0.82*
	$\bar{X}$	1.07[b]	0.47[b]	2.65[a]	0.88[b]	0.95[b]	0.21***
Total volatiles	0	0.25[b]	0.09[bc]	0.46[a]	0.03[c]	0.06[bc]	0.04***
	12	13.58[b]	3.01[d]	30.65[a]	1.52[d]	5.02[c]	0.53***
	24	16.52[b]	3.13[c]	31.73[a]	1.57[c]	5.00[c]	1.11***
	36	16.98[b]	3.10[c]	32.22[a]	2.17[c]	4.40[c]	1.03***
	48	13.90[b]	2.12[c]	29.36[a]	2.10[c]	4.89[c]	1.06***
	$\bar{X}$	12.24[b]	2.29[d]	24.88[a]	1.48[d]	3.87[c]	0.38***

[1]Means are averages of 6 determinations (2 per 3 replicates) expressed in parts per million.
[2]PH = Partially hydrogenated, H = Hydrogenated.
[3]Standard error of the mean.
[4]Not significant.
[5]Treatment mean computed across 0-48 hr of heating.
[abcd]Means within the same row sharing a common letter are not significantly different at $p<0.05$.
*, **, *** Significant at $p<0.05$, $p<0.01$ and $p<0.001$, respectively.

the present study which correlated significantly with sensory aroma/flavor data and which have been reported to affect aroma/flavor of fried convenience foods (Jacobson, 1991; Miller and White, 1988b; Schieberle and Grosch, 1981; Rho et al., 1986; Blumenthal et al., 1979).

Data for initial (0 hr) pentane values indicate small but significant ($p<0.001$) differences among the fat treatments (Table 15). Initially, fresh PH canola had a significantly higher pentane level than both PH soy and tallow which also differed from H soy and H canola. Fresh H canola had the lowest pentane level. Except for the pentane level in tallow which increased slightly, pentane values for all fat treatments increased after 12 hr and remained stable in all fats with further heating. At 12 and 36 hr of heating, the pentane content of PH canola was higher ($p<0.001$) than that of PH soy which was also greater than that of the H fats and tallow which were similar. At 24 and 48 hr, both PH canola and PH soy were similar and higher ($p<0.001$) in pentane than the H fats and tallow which did not differ. The amount of pentane in the H vegetable fats was similar to the animal fat tallow throughout the 48 hr of frying. Overall treatment means for pentane levels in the fats across 0-48 hr were similar to those noted in fats at 12 and 36 hr of heating.

Initially, all frying fats had the same low levels of hexanal (Table 15). Hexanal values in the fats increased

during the first 12 hr of heating and generally remained constant with continued frying. At 12, 24 and 36 hr of frying, PH soy had significantly ($p<0.01$; $p<0.001$) higher hexanal levels than the other fats which were the same. After 48 hr, PH soy contained the highest ($p<0.001$) amount of hexanal, followed by PH canola which differed from both H soy and tallow; H canola had the lowest hexanal value after 48 hr of heating. Treatment means over 0-48 hr of frying show that PH soy had the highest ($p<0.001$) hexanal content followed by both PH canola and tallow, however tallow was similar to H soy which also differed significantly from H canola.

Results for initial 2-heptenal values in the fat treatments were similar and low (Table 15). In the first 12 hr heating period, 2-heptenal values increased for all fat treatments and then remained relatively stable with further heating. At 12 hr, PH soy had a higher ($p<0.05$) level of 2-heptenal than the H fats and tallow which were the same, however 2-heptenal values in PH canola were similar to those of all fats. At 24 and 36 hr, PH soy had a higher ($p<0.001$) level of 2-heptenal than PH canola which was also higher in 2-heptenal than H soy; H canola and tallow had similar low levels of 2-heptenal. After prolonged frying (48 hr), except for H soy which did not differ from tallow, 2-heptenal values similar to those noted in the fats at 24 and 36 hr were found. Overall treatment means for 2-heptenal show significant

differences that were similar to those found among the fat treatments at 24 and 36 hr of frying.

Data for 2,4-heptadienals values among fat treatments were not significantly different initially (0 hr) and after 24 hr of frying (Table 15). However at 12 hr, PH canola contained significantly ($p<0.001$) higher levels of 2,4-heptadienals than both PH soy and tallow, but 2,4-heptadienals values in tallow did not differ from H canola which also had higher levels of 2,4-heptadienals than H soy. After 36 hr, both PH fats had higher ($p<0.01$) levels of 2,4-heptadienals than H soy but they were similar to H canola and tallow in 2,4-heptadienals content. At 48 hr, PH canola contained more ($p<0.001$) 2,4-heptadienals than both PH soy and tallow, which also differed from both the H fats which had similar low 2,4-heptadienals levels. Overall treatment means for the fats show that PH canola had the highest ($p<0.05$) level of 2,4-heptadienals followed by both PH soy and tallow; however, tallow did not differ from H canola which was also similar to H soy in 2,4-heptadienals content.

Data for initial (0 hr) 2-octenal values among fat treatments were similar and low (Table 16). During the initial heating period (12 hr), 2-octenal levels increased for all treatments and remained relatively stable with additional frying. At 12 hr, PH soy contained significantly higher

amounts of 2-octenal than H soy, which was also higher in 2-octenal content than PH canola, H canola and tallow. After 24 hr of frying, except for PH soy which remained highest ($p<0.001$) in 2-octenal content, all other treatment fats were the same. After 36 hr, 2-octenal values in PH soy were higher than PH canola and H vegetable fats, however tallow had a lower ($p<0.001$) 2-octenal level than these fats. At 48 hr of heating, PH soy had the highest ($p<0.001$) 2-octenal content followed by both PH canola and H soy which were similar and differed from tallow, but tallow also had more 2-octenal than H canola. Overall treatment means show that the 2-octenal content of PH soy was higher ($p<0.001$) than H soy which differed from PH canola, which in turn had more 2-octenal than both H canola and tallow.

Small but significant ($p<0.05$) differences in the initial levels of 2,4-decadienals in the frying fats were found (Table 16). Initially (0 hr), except for PH soy which contained more 2,4-decadienals than H soy, all treatment fats were similar. After 12 hr of heating, 2,4-decadienals in all fats increased and except for PH soy, all fats remained relatively stable with further heating. At 12 hr, PH soy had significantly ($p<0.001$) higher amounts of 2,4-decadienals than PH canola, H soy and tallow which were similar, however H soy and tallow did not differ from H canola which had the lowest 2,4-decadienals content. After 24 hr, no significant differences

in 2,4-decadienals among the fats were evident. After 36 hr, PH soy had higher ($p<0.01$) 2,4-decadienal levels than the other fat treatments. At 48 hr, except for PH soy which had higher ($p<0.05$) amounts of 2,4-decadienals than H canola, all fat treatments were the same. Treatment means across 0-48 hr of frying, show that PH soy had significantly ($p<0.001$) higher amounts of 2,4-decadienals than other fats.

Data for total volatiles of fresh fats (0 hr) (Table 16), indicate small but significant differences: PH soy contained higher ($p<0.001$) amounts of total volatiles than PH canola, H canola and tallow which were similar, however H canola and tallow did not differ from H soy which was lowest in total volatiles. During the initial 12 hr heating period, total volatiles for all fats increased markedly; however, increases in total volatiles in PH fats were more marked than in the H fats and tallow. At 12 hr, PH soy had higher ($p<0.001$) amounts of total volatiles than PH canola which also had more total volatiles than tallow; the H fats which were the same had the lowest amounts of total volatiles. After 24, 36 and 48 hr of heating, total volatiles in PH soy were higher ($p<0.001$) than in PH canola which was also higher in total volatiles than the H fats and tallow, which did not differ. Treatment means across 0-48 hr of heating show total volatiles in the fats to be similar to those noted at 12 hr.

Findings of the current study for the volatile constituents produced in the fats during frying are illustrated in Figures 8 and 9. Hydrogenation of the vegetable frying fats increased H fat thermal stabilty compared to PH fats. Results show PH fats to be more susceptible to the production of volatiles which is indicative of oxidative deterioration.

Examination of GC data from the present study for PH fats shows that PH soy contained more hexanal, 2-heptenal, 2-octenal, 2,4-decadienals and total volatiles than PH canola; however, PH canola had higher amounts of pentane and 2,4-heptadienals than PH soy. The GC data for the H fats show that H canola had less hexanal, 2-heptenal, 2-octenal than H soy but similar levels of pentane, 2,4-heptadienals, 2,4-decadienals and total volatiles. Soybean fats and oils constitute 80% of US oil production (Miller and White, 1988a) and soybean fats are used extensively to fry foods (Orthoefer, 1987). The similar GC results obtained for H canola and H soy in the current study, suggest that H canola may also have good potential for use in deep fat frying.

In the present study, the GC data for the H fats and tallow over the 48 hr of frying, show that H fats tended to have similar or lower levels of volatile constituents than tallow. A recent french fry study (Hawrysh et al., 1992b) noted that H soy fat had the lowest level of total volatiles, followed by H canola and tallow, respectively.

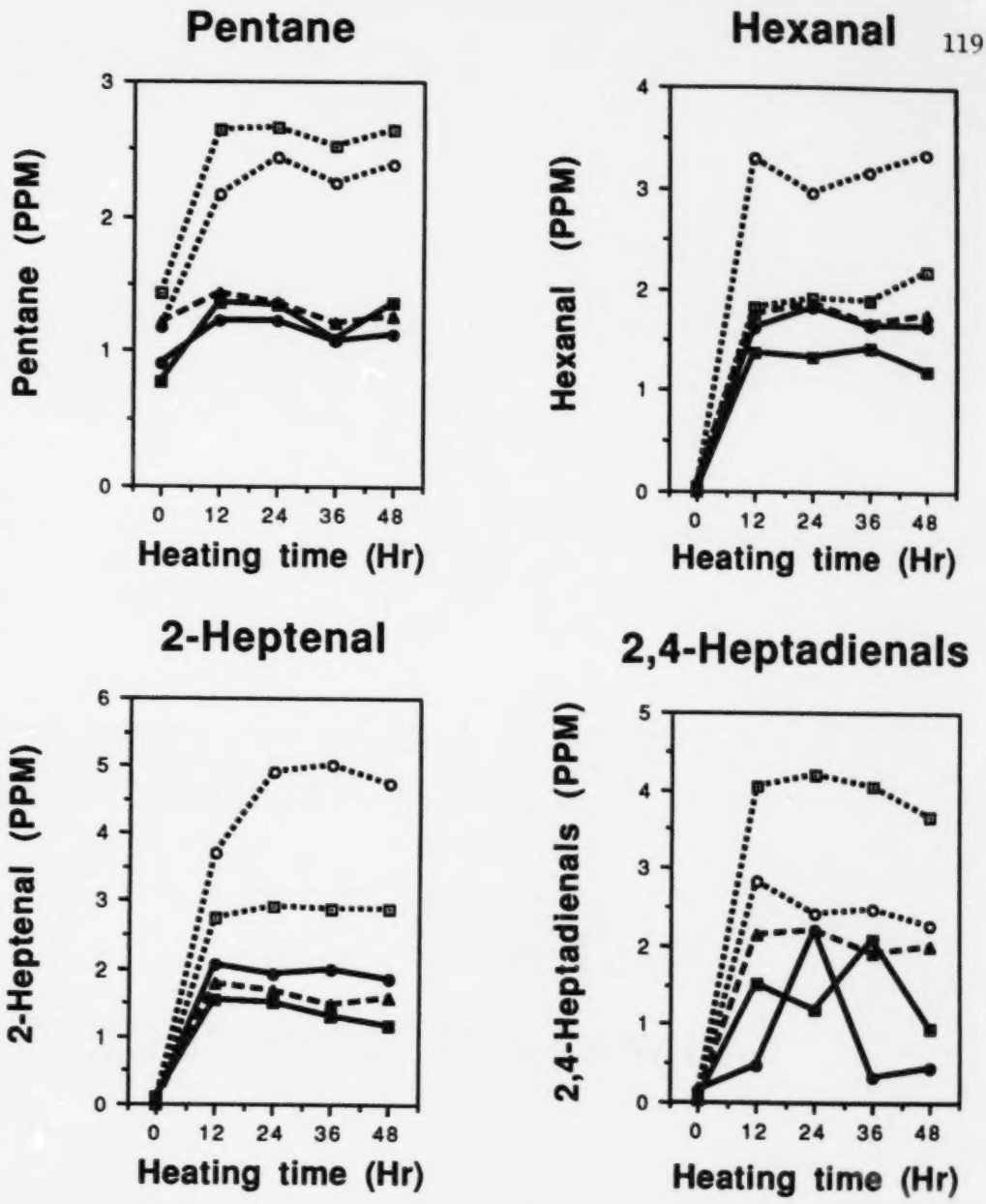


Figure 8. Pentane, hexanal, 2-heptenal and 2,4-heptadienals formed in heated (177^{o}C) frying fats for 0, 12, 24, 36 and 48 hr.

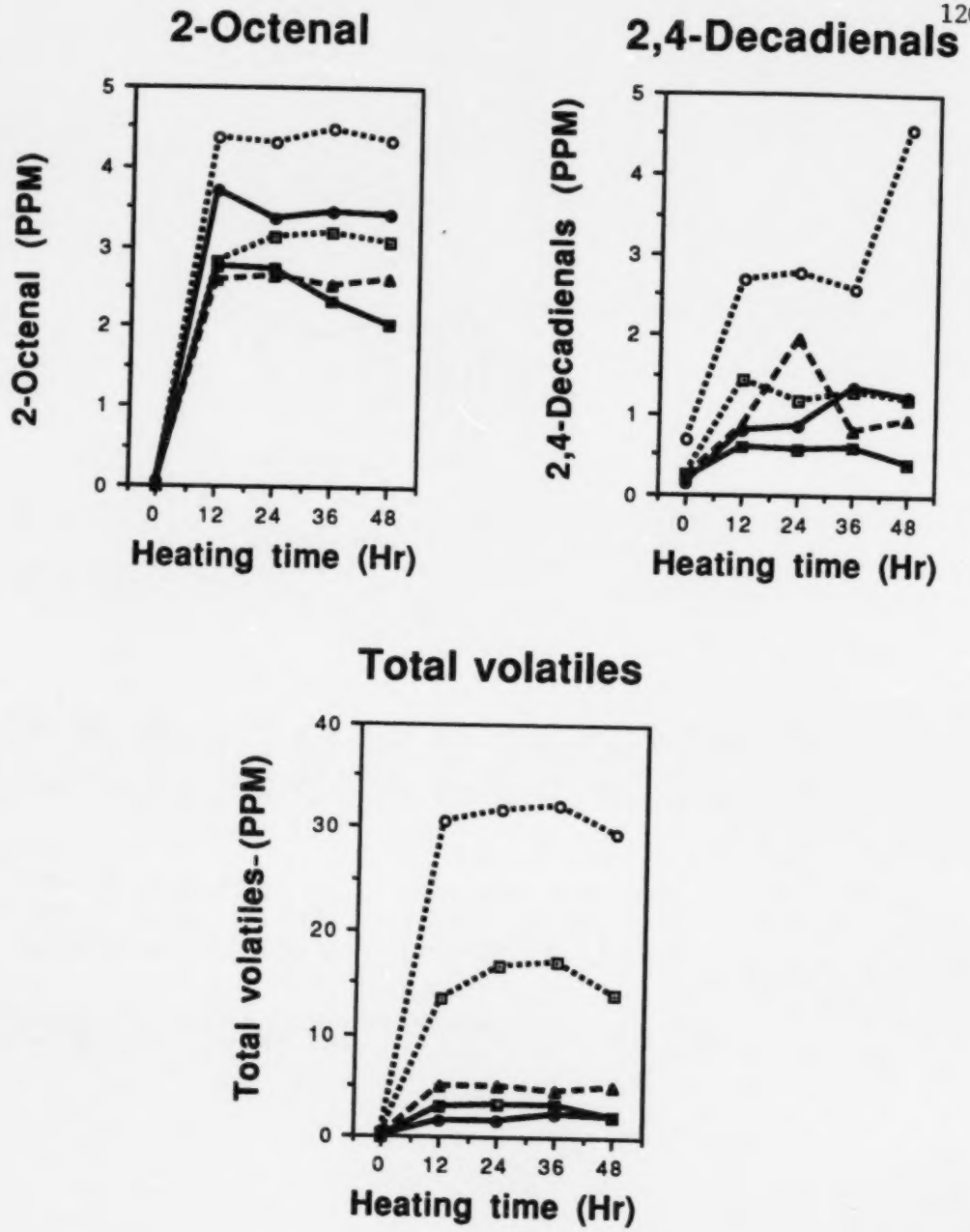


Figure 9. 2-Octenal, 2,4-decadienals and total volatiles formed in heated (177^{o}C) frying fats for 0, 12, 24, 36 and 48 hr.

The GC results of the present research suggest that compared to tallow, the H fats were equally or more oxidatively stable. In addition, data for total volatiles produced in heated H fats tend to support AV and absorbance ($E^{1\%}_{1cm}$) values at 234 nm determined for the H vegetable fats. Moreover, taste panel data indicate that chicken patties fried in the H vegetable fats and tallow, which had low levels of volatiles, were similar in chickeny, meaty and heated oil aromas/flavors. Thus GC, chemical and sensory data show that hydrogenated vegetable fats appear to have potential as high quality frying fats and may serve as replacements for traditionally used animal fats.

Correlations Between GC Data for Frying Fats and Sensory Data for Chicken Patties

Significant correlations between volatile constituents in the frying fats and sensory data from fried chicken patties were found (Table 17). Except for the rancid characteristic which had few significant relationships, most volatile compounds had fair (r=0.26-0.50) to good (r=0.51-0.75) (Leporiere, 1976) correlations with sensory aroma and flavor attributes. As expected, except for 2,4-decadienals, negative coefficients were found for aroma/flavor chickeny and meaty notes with GC data while positive correlations were obtained for GC data with heated oil aroma/flavor notes. No

Table 17. Pearson correlation coefficients (r) between sensory aroma and flavor data for chicken patties and gas chromatographic data for frying fats.

Volatile compound	AROMA				FLAVOR			
	Chickeny	Meaty	Heated oil	Rancid	Chickeny	Meaty	Heated oil	Rancid
Pentane	-0.33**	-0.33**	0.43***	0.21	-0.32*	-0.25*	0.32*	0.01
Hexanal	-0.38**	-0.36**	0.52***	0.22	-0.39**	-0.27*	0.47***	-0.07
2-Heptenal	-0.44***	-0.42***	0.61***	0.27*	-0.41***	-0.32*	0.53***	-0.01
2,4-Heptadienal	-0.38**	-0.43***	0.27*	0.21	-0.45***	-0.39**	0.03	-0.17
2-Octenal	-0.20	-0.20	0.42***	0.06	-0.18	-0.14	0.35**	-0.15
2,4-Decadienals	0.48***	0.35**	-0.36**	-0.32*	0.41**	0.22	0.02	-0.12
Total volatiles	-0.55***	-0.49***	0.65***	0.35**	-0.55***	-0.37**	0.61***	0.01

*, **, *** Significant at $p<0.05$, $p<0.01$ and $p<0.001$, respectively.

explanation for the sign on correlations determined between 2,4-decadienals and aroma/flavor notes is readily apparent. Correlations of volatiles formed in heated frying fats and sensory attributes of fried convenience foods are lacking.

5. SUMMARY AND CONCLUSIONS

In this study commercial frying fats: partially hydrogenated (PH) canola, hydrogenated (H) canola, PH soy, H soy and tallow were evaluated to determine their effect on chicken pattie quality. The exact composition of each of the fat treatments is given in Table 1 page 8. Each frying fat treatment was heated (177°C±2°C) for four 12 hr periods for a total of 48 hr. Chicken patties were fried intermittently during each frying period. Instrumental, chemical and sensory methods were used to assess chicken pattie quality. Performance of fats extracted from patties and of frying fats was also determined using chemical and instrumental methods.

Except for the first 12 hr period of heating, significant differences in chickeny aroma/flavor among chicken patties fried in the fat treatments were found. Overall treatment means of chicken patties fried in the fats showed that H canola, H soy and tallow patties were similar and more ($p<0.001$) chickeny in aroma/flavor than those fried in the PH fats. No differences in chicken pattie meaty aroma/flavor due to frying fats were noted at 12, 24 and 36 hr of heating. The overall treatment means of chicken patties showed the H fats and tallow were similar and more ($p<0.001$) meaty in odor than patties from the PH fats, but only more meaty in flavor than PH canola patties. Fried foods cooked in tallow may exhibit

desirable meaty flavors (Sinram and Hartman, 1989). However in the present study, no differences in meaty flavor were noted among patties cooked in the H vegetable fats and tallow. Patties fried in the PH fats had a more intense heated oil aroma/flavor than H canola, H soy and tallow patties, but patties from all fats were low in rancid aroma and flavor.

Sensory texture and juiciness data of chicken patties fried in the fat treatments generally showed few significant differences throughout heating. Highly saturated fats such as H canola, H soy and tallow when used in deep fat frying may contribute to an oily mouthfeel in fried foods (Sinram and Hartman, 1989; Stevenson et al., 1984a). In the present study, patties from all fats were similar in oily mouthcoating. Overall treatment means showed that H canola, H soy and tallow patties were similar and more ($p<0.01$) tender than PH soy patties. Chicken patties fried in the PH fats were similar and more ($p<0.001$) juicy than those fried in the H fats and tallow. Patties fried in H canola were lighter in color than the PH fat patties which were the same. Except for rancid aroma, overall treatment means of patties cooked in the H fats and tallow generally did not differ in aroma and flavor notes, texture, juiciness and color. Thus the sensory attributes of chicken patties cooked in H vegetable fats and tallow patties were similar. Instrumental texture and juiciness data for chicken patties showed no differences due to frying fats. Findings of the present study showed that

trained panelists were more able to detect small differences in sensory texture among the treatment patties than were the instrumental tests.

The quality of fried chicken patties was assessed via chemical methods by analyzing fats extracted from patties. There were no significant differences in the PV of fats extracted from patties due to frying fat treatment. However, data for UV absorbance values ($E^{1\%}_{1cm}$) at 234 and 268 nm in fats extracted from patties over the 48 hr of heating showed good ($p<0.001$) correlations with sensory aroma and flavor data. Evaluating potato chip quality, Hawrysh (1992a) also found good to excellent correlations between sensory rancid and painty notes and absorbance values ($E^{1\%}_{1cm}$) at 234 nm. Based on their frying study, Gwo et al. (1985) stated that absorbance values ($E^{1\%}_{1cm}$) at 234 nm were reliable predictors of sensory scores. Further research on the relationship between chemical parameters and sensory fried food quality is warranted.

During the 48 hr of heating, all fats generally sustained minimal thermal degradation as measured by chemical and instrumental methods. As expected, IV for all fats differed significantly ($p<0.001$) due to varying levels of hydrogenation. Data for IV, PV and %FFA showed that fats remained relatively stable over the entire frying period and were of good quality. Anisidine value overall treatment means

and absorbance value ($E^{1\%}_{1cm}$) at 234 nm overall treatment means for the H fats were similar and lowest, followed by tallow, PH canola and PH soy which all differed. The AV and absorbance value ($E^{1\%}_{1cm}$) at 234 nm data also tended to support sensory findings which indicated that the heated oil aroma/flavor of the PH fat chicken patties was most intense. With continued frying, all fats darkened and increased slightly in viscosity due to fat degradation. However the small but significant color and viscosity differences found among the heated fats appear to be due to initial fat color and viscosity. Dielectric constant overall treatment means for all fats were similar and low. The smoke point overall treatment means reflect initial fresh fat smoke point values. After 36 hr of frying, the smoke points for the H fats and tallow were below 170°C and after prolonged frying (48 hr), both the PH fats had higher ($p<0.01$) smoke points than the H fats and tallow which were similar. However, all fats had smoke points that were lower than 170°C after 48 hr of heating. Smoke point determination was the only quality parameter which indicated that the frying fats were of poor quality after 36-48 hr of frying. Smoke point measurements in the present study were determined using the official AOCS method. However, smoke points determined via the AOCS method have been reported to vary by ± 25°C from one laboratory to another (Stevenson et al., 1984b). Generally, AV and absorbance values ($E^{1\%}_{1cm}$) at 234 nm indicate that the PH fats were less thermally stable and

exhibited more thermal degradation than H fats. The H vegetable fats were more thermally stable than tallow suggesting H fats performed well during continued use at elevated temperatures.

Findings of the current study for volatile constituents produced in the fats during frying show that the H fats were more thermally stable than the PH fats. PH soy contained more hexanal, 2-heptenal, 2-octenal, 2,4-decadienals and total volatiles than PH canola; but PH canola had higher amounts of pentane and 2,4-heptadienals than PH soy. The GC data for the H fats show that H canola had less hexanal, 2-heptenal, 2-octenal than H soy but similar levels of pentane, 2,4-heptadienals, 2,4-decadienals and total volatiles. The GC data for H fats and tallow over the frying period show that the H vegetable fats tended to have similar or lower levels of volatile constituents than tallow. The GC results suggest that compared to tallow, the H fats were equally or more thermally stable.

The GC data of the current research support the sensory findings which show that as volatile constituents increased in heated PH vegetable frying fats, the chickeny and meaty aroma/flavor notes detected in the chicken patties by the trained panelists tended to decrease while the heated oil aroma and flavor notes became more noticeable. Moreover, GC analyses support sensory data which show chicken patties

cooked in hydrogenated vegetable fats possess desirable chickeny and meaty aroma/flavors similar to those of patties fried in tallow. Thus H vegetable fats have potential as high quality frying fats for convenience foods such as chicken patties and may serve as replacements for traditionally used animal fats.

Thus in this study, the performance of each frying fat has been shown to influence the quality of the fried chicken patties. Findings of the current research show that both H canola and H soy were similar and performed equally or better than tallow according to the chemical/instrumental and sensory parameters assessed in the frying fats and patties. The H canola and H soy were more thermally and oxidatively stable than their PH counterparts. Chicken patties fried in the PH fats tended to have a more intense heated oil aroma and flavor than those fried in H fats and tallow. Thus there appears to be considerable potential for increasing the usage of H canola fats for frying convenience foods. Although many studies have focused on frying fat performance, evaluations of the effects of frying fats on the quality attributes of convenience foods such as chicken in conjunction with frying fat performance are lacking. Further research designed to compare the sensory quality of other convenience foods, such as battered fish products fried in canola fats and other commonly used frying fats (soybean, tallow) is pertinent.

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Appendix 1. Fat randomization to fryers for three replications[a].

	Fryers		
Fat Treatment	Rep[b] 1	Rep 2	Rep 3
PH[c] canola	1	3	2
H canola	2	4	5
PH soy	3	6	4
H soy	4	2	3
Tallow	5	1	6
HREF[d]	6	5	1

[a] Fryers were labelled 1-6.
[b] Rep = Replication.
[c] PH = Partially hydrogenated; H = Hydrogenated.
[d] HREF = Hidden reference.

Appendix 2. Portioning of fresh and used fats.

Portioning of fresh fats.

Test	Partially hydrogenated fats	Hydrogenated fats and tallow[a]
Smoke point	250 mL bottle	250 g
Viscosity	50 mL bottle	100 g
Chem 1[b]	20 mL vial	24 g
Chem 2[c]	20 mL vial	16 g
Chem 3[d]	7 mL vial	15 g
Color	7 mL vial	15 g
GC	7 mL vial	2 g

[a] Solid fats were portioned into 4 lb plastic bags.
[b] Chem 1 = % Free fatty acids and peroxide value tests.
[c] Chem 2 =p-Anisidine value and absorbance ($E^{1\%}_{1cm}$) at 234 and 268 nm.
[d] Chem 3 = Iodine value test.

Portioning of used fats.

Test	Amount of fat sample
Smoke point	250 mL bottle
Viscosity	50 mL bottle
Chem 1[a]	20 mL vial
Chem 2[b]	7 mL vial
Chem 3[c]	7 mL vial
Color	7 mL vial
GC	7 mL vial

[a] Chem 1 = % Free fatty acids and peroxide value tests.
[b] Chem 2 = p-Anisidine value and absorbance ($E^{1\%}_{1cm}$) at 234 and 268 nm.
[c] Chem 3 = Iodine value test.

Appendix 3. Descriptive terms provided to assist panelists in the evaluation of aroma and flavor characteristics of chicken patties.

Meaty	Chickeny	Ammonia-like
Acidic	Sulfury	Bland
Fishy	Salty	Foreign
Doughy	Metallic	Bitter
Artificial	Off-flavor	Rancid
Burnt/Acrid	Sweet	
Spicy	Stale	Buttery
Nutty	Heated oil	Oily mouthcoat
Breadcrumb/toasty		

Appendix 4. Final questionnaire for the evaluation of chicken patties.

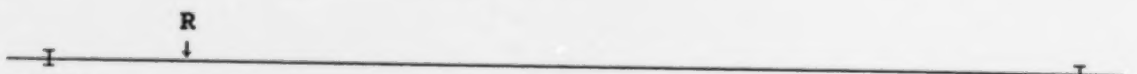
Evaluation of chicken patties

Code_____ _____ _____ _____ _____ _____ _____

AROMA - Chickeny Intensity

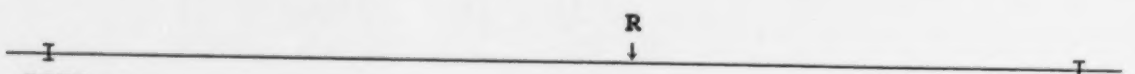
AROMA - Meaty Intensity

AROMA - Heated oil Intensity



AROMA - Rancid Intensity

FLAVOR - Chickeny Intensity



FLAVOR - Meaty Intensity

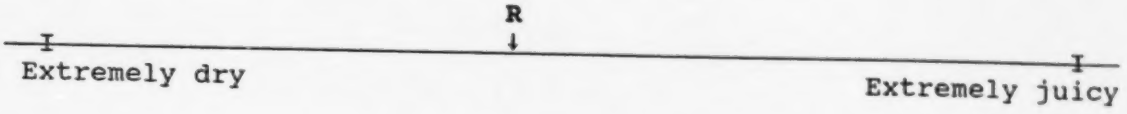
FLAVOR - Heated oil Intensity

FLAVOR - Rancid Intensity

Appendix 4. Continued.

Oily Mouthcoating

JUICINESS



TENDERNESS

Code_____ _____ _____ _____ _____ _____ _____

No. of chews _____ _____ _____ _____ _____ _____ _____

COLOR

Comments are welcome:
code_____

code_____

code_____

code_____

code_____

code_____

Appendix 5. Tasting procedures for the evaluation of chicken patties.

Tasting procedures for the evaluation of chicken patties.

Please rinse your mouth with lemon water before beginning and between samples, and taste the samples in the order presented to you.

Aroma - aroma or odor is the quality of a substance which affects the sense of smell.

Procedure - Using 1 wedge of chicken, bring the sample to directly beneath the nose and inhale quickly three short sniffs, then mark on the scale where you think it is.

*** For Chickeny aroma - sniff meat side of sample.
Heated oil
Rancid aroma - sniff crust side of sample.

Flavor - flavor is the intensity of the chickeny flavor, or heated oil or rancid flavor remaining in the mouth after complete mastication.

Procedure - first evaluate aroma via sniffing 3 times then bite down chicken wedge with molar teeth and chew until completely masticated, recording on the line where you think the intensity of the specific flavor is.

Tenderness - Is the amount of effort and time required to completely masticate a wedge of chicken before swallowing.

Procedure
Bite the sample with the molar teeth and count exactly the number of chews used before swallowing. Record on the line where you think the degree of tenderness is.

Oily Mouthcoating
The amount of oiliness on the mouth, tongue and lips after chewing and swallowing the sample.

Juiciness
Refers to your impression of the moistness of the sample after 5 chews. An anchor is provided to standardize scores. Please chew the anchor 5 times - score, and then chew the reference 5 times and score where you think the reference is relative to the raisin (anchor).